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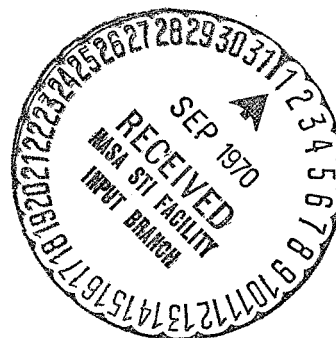
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NASA PROGRAM APOLLO WORKING PAPER NO. 1192

THE DESIGN AND TESTING OF A THREE-MAN COUCH PLATFORM  
FOR POSSIBLE USE IN THE APOLLO COMMAND MODULE

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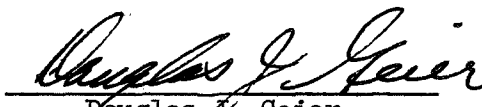
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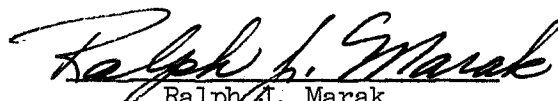
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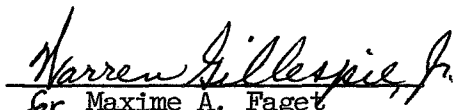
THE DESIGN AND TESTING OF A THREE-MAN COUCH PLATFORM  
FOR POSSIBLE USE IN THE APOLLO COMMAND MODULE

Prepared by:   
Douglas J. Geier  
Systems Test Branch

  
Ralph J. Marak  
Systems Development Branch

  
Earl Hensley, Jr.  
Systems Test Branch

Authorized for Distribution:

  
or Maxine A. Faget  
Assistant Director for Engineering and Development

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
MANNED SPACECRAFT CENTER  
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Houston, Texas 77058
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6571st Aeromedical Field Laboratory  
Holloman AFB, New Mexico

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# THE DESIGN AND TESTING OF A THREE-MAN COUCH PLATFORM

## FOR POSSIBLE USE IN THE APOLLO COMMAND MODULE

By Douglas J. Geier and Earl Hensley, Jr.  
Systems Test Branch  
and Ralph J. Marak  
Systems Development Branch

### SUMMARY

To determine if a lightweight version of the Apollo contractor couch and restraint system could be designed and satisfactorily fabricated, an MSC inhouse program was initiated to design, fabricate, and test a prototype couch-restraint system applicable to the Apollo command module. The objectives used in the design of the three-man couch system were to minimize weight, maintain interchangeability with the Apollo command module strut system and maintain compatibility with the necessary motions required of the Apollo couch system.

Structural integrity and human deceleration tests were conducted on the "Daisy Track," Holloman Air Force Base, New Mexico.

These tests provided excellent base line data on possible man-machine interface problem for the Apollo spacecraft.

Results of the human testing indicate no apparent problems in force tolerability or man-machine interface when subjecting the couches to the anticipated Apollo water landing linear deceleration.

### INTRODUCTION

As part of the initial Apollo spacecraft development program, North American Aviation (NAA), S&ID, had produced a three-man couch system to meet NASA impact requirements for Block I spacecraft. To determine if a lightweight version of this system could be designed and satisfactorily built, a NASA inhouse program was initiated to design, fabricate, and test a prototype system. This Apollo couch-restraint system backup development program has been completed.

The objectives used in the design of the three-man couch system were to minimize weight, maintain interchangeability with the Apollo command module strut system and maintain compatibility with the necessary motions required of the Apollo couch system. A prototype restraint system was used which very closely duplicates the restraint system being fabricated for use in the Apollo command module.

Structural integrity and human abrupt deceleration tests were conducted on the "Daisy Track," Holloman Air Force Base, New Mexico. The structural integrity runs were made with anthropomorphic test dummies as couch occupants to check out the overall system and to provide the Aeromedical Laboratory personnel the necessary confidence in the structural integrity of the system to subsequently allow the use of their subject panel as couch occupants during the human portion of the test program. Human runs were required to check out the tolerability and man-hardware interface when subjecting the couches to the anticipated Apollo linear landing loads.

Force directions used during these tests were those which would simulate decelerations in the eyeballs in (EBI), eyeballs in and up (EBI & EBU), and eyeballs right or left (EBR or EBL) directions, depending on the yaw angles. Decelerations magnitudes applied to the couches were 13 to 15g in the EBI direction and 7 to 12g EBR or EBL (lateral) directions.

Results of the human testing indicate no major problems in load tolerability or man-machine interface when subjecting the couches to the anticipated water landing linear deceleration.

## SYMBOLS AND ABBREVIATIONS

EBI	Eyeballs in, deceleration direction caused by force water from back to chest (transverse force)
EBD	Eyeballs down, deceleration direction caused by force vector from feet to head (headward force)
EBL	Eyeballs left, deceleration direction caused by force vector from left to right (lateral force)
EBR	Eyeballs right, deceleration direction caused by force vector from right to left (lateral force)
EBU	Eyeballs up, deceleration direction caused by force vector from head to feet (tailward force)
$G_X$	Transverse deceleration, X-axis
$G_Y$	Lateral deceleration, Y-axis
$G_Z$	Longitudinal deceleration, Z-axis
Y-Y	Lateral axis within the Apollo command module
Z-Z	Longitudinal axis within the Apollo command module
X-X	Transverse (vertical) axis within the Apollo command module
$G_R$	Resultant deceleration
$G_{in}$	Couch input deceleration



## SYSTEM COMPONENTS AND COUCH APPARATUS

### Couch

The primary considerations in designing the couch system were to minimize weight, to maintain interchangeability with the Apollo command module load attenuation struts, simplicity, and to maintain compatibility with the necessary couch motions required for use in the Apollo command module. The external size of the couch platform was restricted to that of the Apollo spacecraft envelope. The arrangement of the back pans and seat pans was such as to offer the maximum space, within the spacecraft envelope, for crew comfort. Seat pan adjustability was accomplished by a pin positioning arrangement. Armrests, seat pan, and docking controls were located approximately in the same locations as contractor equipment. The couch platform was fabricated from 6061-T6 and 7075-T6 aluminum and was a welded-riveted structure, weighing 215 pounds. All fabrication of the couches was accomplished in the MSC, Technical Services Shops.

Photographs of the couch-restraint system and sled test fixture are presented in figure 1.

### Restraint Harness

The restraint harness configuration used throughout these tests consisted of shoulder straps, lap belt, and a side "V", details of which are shown in figures 1(a) and 2. This configuration very closely duplicates the harness design being fabricated by North American Aviation (NAA) for Apollo Block I to meet the criteria required by Crew Systems Division.

All harness and couch padding was fabricated by the Restraint and Support Section Restraint Laboratory. The couch padding approximated in size and geometry the padding being fabricated by NAA for use in the Apollo command module couches.

### Test Fixture

The test fixture as shown in figures 1 and 3 was designed to allow variations in couch pitch angle over a range of 0 to 90°. Yaw angle variations over a range of 0 to 360° were obtained by turning the complete couch-fixture system on the sled.

### Instrumentation

CEC strain gage accelerometers were mounted on the head support, back pan, and seat pans of each couch and on the sled during the 0° and 30° pitch structure runs. Triaxial accelerometer configurations were mounted on the bottom of the center couch seat pan and a linear accelerometer was located on the sled for the lateral and 60° pitch runs. The accelerometer locations are shown in figures 3(a) and 3(b). Human subject decelerations were recorded by the use of a chest pack triaxial accelerometer configuration as shown in figure 3(c). EKG and respiration physiological measurements were also recorded for each subject, during each human run.

### Photography

Pre-test, impact, and post-test still photographs were taken during all human runs. Motion pictures at impact were taken for all dummy and human runs from three locations at a film speed of 1000 frames/sec.

### TEST PROCEDURES

#### Integration Tests

The purpose of these tests was to evaluate the reach, vision, and motion capabilities of crew members of the Apollo spacecraft when lying in the three-man couch platform. The evaluation was conducted with couch occupants suited in both pressurized and unpressurized space suits. The tests also evaluated the couch adjustment and adjustment controls as to motion capabilities and usability. Equipment used to perform these tests was as follows:

1. Human subjects
2. Space suits as necessary to fit subjects and support these tests. These pressure suits were the early prototype Hamilton Standard suits, commonly called Hecmar suits, with a 28-30 inch shoulder width.
3. Inhouse FAB three-man couch platform.
4. CSD Apollo mockup
5. Space suit console

After all equipment had been assembled, the subjects were dressed in prototype Hamilton Standard Apollo space suits, and put into the

spacecraft mockup. The tasks which were performed by the subjects were as follows:

1. Enter couch
2. Hook up and adjust harness
3. Change thigh pan position to  $66^\circ$
4. Change thigh pan position to  $108^\circ$
5. Center couch: drop thigh pan and get out of couch
6. Get back into couch and readjust thigh pan to  $108^\circ$
7. Center and left-hand couch: get out of couches and go to docking tunnel (to be done only with three subjects).
8. Move couch into docking position (one man)
9. Move couch back to flight position (one man)
10. From seven: Two men return to couch from docking tunnel
11. Perform reach and vision test
12. Leave couches

The items above were to be performed by one and three subjects. The items were repeated, with the exception of items 7, 8, 9, and with one subject in a space suit pressurized to a pressure differential of 3.5 psi.

In order to check the possible reach and vision limitations of the subject, the above procedure, involving the outboard couch, was performed both at the normal flight position and with the couch's headrest and armrests moved  $\frac{3}{4}$  inch and  $1\frac{1}{2}$  inch outboard, respectively.

All items were evaluated by the comments of the subjects as to their limitations and capabilities and whether these limitations were believed to be due to the space suit used or the couch system being evaluated. Measurements were also to be taken at the following places for body shift in the Y-Y direction relative to the side wall of the command module: (1) head, (2) shoulder, (3) elbows, and (4) hips. Results of these measurements are given in figures 6(a) and 6(b).

## Sled Tests

Structural test. - Abrupt deceleration tests were performed on the "Daisy Track" at Holloman Air Force Base. This facility is shown in figure 4. Each run position is indicated in table I. Figure 5 may be used for orientation of roll, pitch, and yaw structural tests which were conducted with anthropomorphic test dummies as couch occupants prior to human runs. The purpose of these tests was to check out the structural capability of the test configuration to deceleration forces of a magnitude of twice those which would be applied to the couches when running with human subjects as couch occupants.

The structural tests consisted of a series of four sled runs per position, with an increasing g load applied of 5, 7, 12, and 24g's with an impact velocity increase from 25 ft/sec to 38 ft/sec.

## Human Tests

The purpose of human tests was to check out the tolerability and man-pressure suit-seat interface when subjecting the couches to applied linear deceleration loads as anticipated during Apollo water landings. Deceleration tests were conducted as indicated in table I. Three runs per position were run, applying 13 to 15g to the couch seat pans, when conducting tests which produce an eyeballs in (EBI) and/or an eyeballs in and up (EBI & EBU) deceleration vector. The couches and couch occupants were in a 0° and 30° pitch position during these runs.

The subject weights were varied for each position and tested at each position. Tests were run on three men: small (145 lb); medium (165 lb); and large (above 175 lb). A lead sheet was attached to the couch back pans as necessary to keep a constant 660-pound weight on the back pans of the couch platform.

To check out movement in the lateral and eyeballs out and down directions, two runs per position for two load conditions were conducted. The loads applied to the seat pan was 7 and 12g, respectively.

Subjects in the weight range of 145 pounds and 175 pounds or above were used. When testing the lateral directions, the couches were in a 60° pitch position. All subjects weighing 165 pounds or under, seated in the center and outboard couches, were dressed in pressure suits.

## DATA PRESENTATION

Various still photographs taken at impact are presented in figures 7(a), 7(b), and 7(c) which show typical limb and facial contortions of the subjects under the impact stress. Typical test recordings from the "Daisy Track" facility are shown in figures 8(a) and 8(b). Repeatability of the sled impact forces and the seat transmittal forces from duplicate sled runs with the same variables are shown in figures 9(a) and 9(b).

Deceleration-time histories showing the force transmission between the sled and couches are shown in figure 10. Couch occupants for these tests were anthropomorphic test dummies. Since the purpose of these runs was the proof loading of the couches, no dummy measurements were taken. An input force of  $24$  and  $7\frac{1}{2}g$ 's are shown in figures 10(a) and 10(b), respectively. An inspection of figure 10 shows that the force transmission from the sled to the couches was generally satisfactory and follow the input curve closely. For high loads the head support measurements are erratic. This was caused by the dummies' head bouncing in and out of the head support, and therefore, the higher the load the more erratic movement of the dummies' head in and out of the couches.

Figure 10 shows in general, a good force transmission between the sled and couch, and between the three couches.

Figures 11 through 18 show comparison of the left-hand, center, and right-hand couch occupants deceleration-time histories through a family of positions and with the weight of the couch occupants varied from 165 pounds to 190 pounds in all cases and to 215 pounds for the  $0^\circ$  roll,  $0^\circ$  pitch,  $180^\circ$  yaw position presented in figure 11(c). The human measurements were taken with a chest pack, tri-axial, accelerometer configuration, strapped to each subject as in figure 3(c). It is felt that with the use of chest pack accelerometers, the deceleration measurements are amplified by the possible vibration of the chest pack, and therefore this data should be used only as an indication and/or guide to possible body measurements or motions instead of actual forces measured on body components.

Comparisons of the left-hand, center, and right-hand couch occupants deceleration-time histories when in a  $0^\circ$  roll,  $0^\circ$  pitch, and  $180^\circ$  yaw test position are presented in figure 11. This position will produce an X direction (EBI) loading. A 13 to 15g input force at a velocity change of 37 ft/sec was applied to the couches. Figures 11(a), 11(b), and 11(c), respectively, present a range of occupant weights from 165 pounds to 215 pounds.

An inspection of figure 11(a) (165 lb subjects) shows the three couch occupants receiving the same type of loading. Although the waveform and duration of the occupants X-axis and resultant deceleration-time histories are generally the same, there is an amplification of the impact load by a factor of 2.2 to 2.6 for a 30-millisecond duration immediately following impact as recorded on the chest pack accelerometer configurations. The reasons for this amplification cannot be definitely determined, but it is reasoned that it might be caused by vibration in the chest pack accelerometers. An inspection of figure 11(b) (190 lb couch occupants) shows the same general trend as for the 165-pound occupants.

The X-direction and resultant deceleration-time histories for 215-pound subjects, as compared in figure 11(c), appear to have an average of a 30-percent (1.5 to 2.2) smaller amplification factor than the lighter subjects, but also have a 60-percent longer exposure to the amplified forces.

The Z-axis and Y-axis deceleration-time histories for all subjects have low peaks as expected.

Comparison of deceleration-time histories for couch occupants in the  $0^\circ$  roll,  $30^\circ$  pitch, and  $180^\circ$  yaw test position is presented in figures 12(a) and 12(b) for 165-pound and 190-pound couch occupants, respectively. This test position would produce X-axis (EBI) and Z-axis (EBU) force vectors.

X-axis and resultant measurements again show an amplification factor of 1.8 to 2.6 for 165-pound occupants, for a 20-millisecond duration following impact. The Z-direction deceleration-time histories appear to have higher peaks than the previous test position, as expected.

In both the X-axis (EBI) test positions, the occupant on the left-hand couch had higher recorded decelerations than the other two couch occupants. The reasons for this is not evident, unless it was caused by a lack of symmetry in the setup assembly. A less rigid connection on the left side of the couches would allow a whip action on the left-hand cantilevered couch, which in turn, could cause the higher forces to be transmitted to the couch occupants.

Figures 13 through 18 show comparisons of deceleration-time histories for couch occupants at different test positions which apply various combinations of lateral (Y-axis) and longitudinal (Z-axis) forces on the couches and occupants. An inspection of these figures shows amplifications in the order of two times the couch loads as measured on the couch occupants in the major forces axes.

## TEST RESULTS

## Integration Tests

Space suit availability and docking mechanism assembly problems dictated the deletion of tasks 8 and 9 of the test procedures and the three-man testing. The latter was replaced with two-man tests. Within the criteria of these tests there were no limitations in the reach and vision capabilities of the crew members when laying the FAB three-man-couch-platform.

The problem areas which were apparent in the couch design are as follows:

1. The subject, in an unpressurized suit, could not operate the adjustment handles located on the thigh pan.
2. Reconnection of the center couch thigh pan from a dropped position to the 108° flight position proved to be a two-man operation. This problem occurs as the subject, returning from the guidance and navigation (G&N) station, sits in the center couch and tries to swing himself and the thigh pan back into flight position. In doing this, his helmet strikes the instrument panel, thereby restricting any further movement. (Note: It is possible that if the subject's feet had been tied in, he would have been capable of lying back in the couch and then, by bringing his feet up, bring the thigh pan back into position.)
3. The webbing for the "V" strap tends to bind on the thigh pan adjustment.
4. Optimum vision capabilities were not achieved.

In order to perform other portions of the tests involving vision, a 2-inch-thick pad was added to the headrest which provided near-optimum vision capabilities.

General comments from observations during the test are as follows:

1. The reach capabilities of the subject proved to be optimum in both a pressurized and unpressurized suit.
2. Shoulder interference, between the subjects, was present to a minor degree in an unpressurized suit and increased with suit pressurization.
3. By adjusting the armrest and head support outboard, shoulder interference showed a marked decrease with no limitations in the reach

and vision capabilities of the subject. The measurements taken between the head, shoulder, elbow, and hip relative to the sidewall of the command module are shown in figures 6(a) and 6(b). These measurements show that the only interface problem which occurs is between the astronaut's elbow and the command module sidewall.

### Sled Tests

The g loads applied to the couch seat pans throughout this program were those experimentally obtained from Apollo model and boiler-plate drop tests which are representative of the anticipated Apollo water landing couch loads and/or the existing couch design loads.

Throughout all the deceleration tests presented, subject debriefing results indicated no subject complaints about the impact forces. Subject displacement was greatest when testing in the lateral force directions, as expected. For nominal lateral landing loads of 5 to 7g's and nominal X-axis direction loads of 13 to 15g's, there appears to be no gross movement between the couch occupants or couch and hardware which would cause degradation of hardware and/or couch occupant injury.

### CONCLUDING REMARKS

#### Integration Tests

The results of the integration tests showed that the following design changes should be made:

1. All handles located on the thigh pan must be positioned so they may be reached and operation simplified.
2. The foot supports should be constructed so that the subject is capable of restraining his feet in the foot support.
3. The "V" strap adjustment on the thigh pans should be replaced and/or modified so that a pull can be executed on the adjustment.
4. The headrest should allow a vertical adjustment of about 2 inches with respect to the launch position, in order to provide better vision capabilities.
5. A mirror should be included as standard equipment and mounted to facilitate harness connection.



Modifications have been incorporated in the NAA unitized couch design which have solved the problem areas as stated in these test results.

#### Sled Tests

1. There appears to be no apparent physiological or man-suit-couch interface problems occurring when g forces of the amplitude and duration used throughout the test program are applied to couches.

2. Base line data have been obtained for comparison with subsequent design verification (man-rating) tests with Apollo flight hardware.

3. A three-man couch configuration, compatible with all Apollo requirements of adjustments, movements, and impact can be built within a weight framework of 215 pounds.

TABLE I. - IMPACT ATTITUDE AND CONDITION FOR THREE-MAN

## COUCH IMPACT PROGRAM

Run	Direction, G	Pitch, deg	Yaw, deg	Roll, deg	AV	G	Subject size
*1	EBI	30	180	0	37	$7\frac{1}{2}$	Large
2	EBI	30	180	0	37	13-15	Large
3	EBI	30	180	0	37	13-15	Medium
4	EBI	30	180	0	37	13-15	Small
5	EBI	0	180	0	37	$7\frac{1}{2}$	Large
6	EBI	0	180	0	37	13-15	Large
7	EBI	0	180	0	37	13-15	Medium
8	EBI	0	180	0	37	13-15	Small
**9	EBR or EBL	60	90	0	37	7	Small
10	EBR or EBL	60	90	0	37	7	Large
11	EBR or EBL	60	90	0	37	12	Small
12	EBR or EBL	60	90	0	37	12	Large
13	EBR or EBL	60	90	0	37	7	Small
14	EBR or EBL	60	90	0	37	7	Large
15	EBR or EBL	60	90	0	37	12	Small
16	EBR or EBL	60	90	0	37	12	Large
17	EBR or EBL	60	90	0	37	7	Small
18	EBR or EBL	60	90	0	37	7	Large
19	EBR or EBL	60	90	0	37	12	Small
20	EBR or EBL	60	90	0	37	12	Large
21	EBR or EBL	60	90	0	37	7	Small
22	EBR or EBL	60	90	0	37	7	Large
23	EBR or EBL	60	90	0	37	12	Small
24	EBR or EBL	60	90	0	37	12	Large

TABLE I. - IMPACT ATTITUDE AND CONDITION FOR THREE-MAN  
COUCH IMPACT PROGRAM - Concluded

Run	Direction, G	Pitch, deg	Yaw, deg	Roll, deg	AV	G	Subject size
***25	EBR or EBL	60	90	0	37	7	Small
26	EBR or EBL	60	90	0	37	7	Large
27	EBR or EBL	60	90	0	37	12	Small
28	EBR or EBL	60	90	0	37	12	Large
29	EBO & EBU	60	0	0	37	7	Small
30	EBO & EBU	60	0	0	37	7	Large
31	EBO & EBU	60	0	0	37	12	Small
32	EBO & EBU	60	0	0	37	12	Large

\* Subject size - runs 1 through 8

Small - average - 165 pounds = subject weight + suit

Medium - average - 190 pounds = subject weight + suit

Large - average - 215 pounds = subject weight + suit

\*\* Subject size - runs 9 through 32

Small under 165 pounds = subject weight + suit

Large over 190 pounds = subject weight + suit

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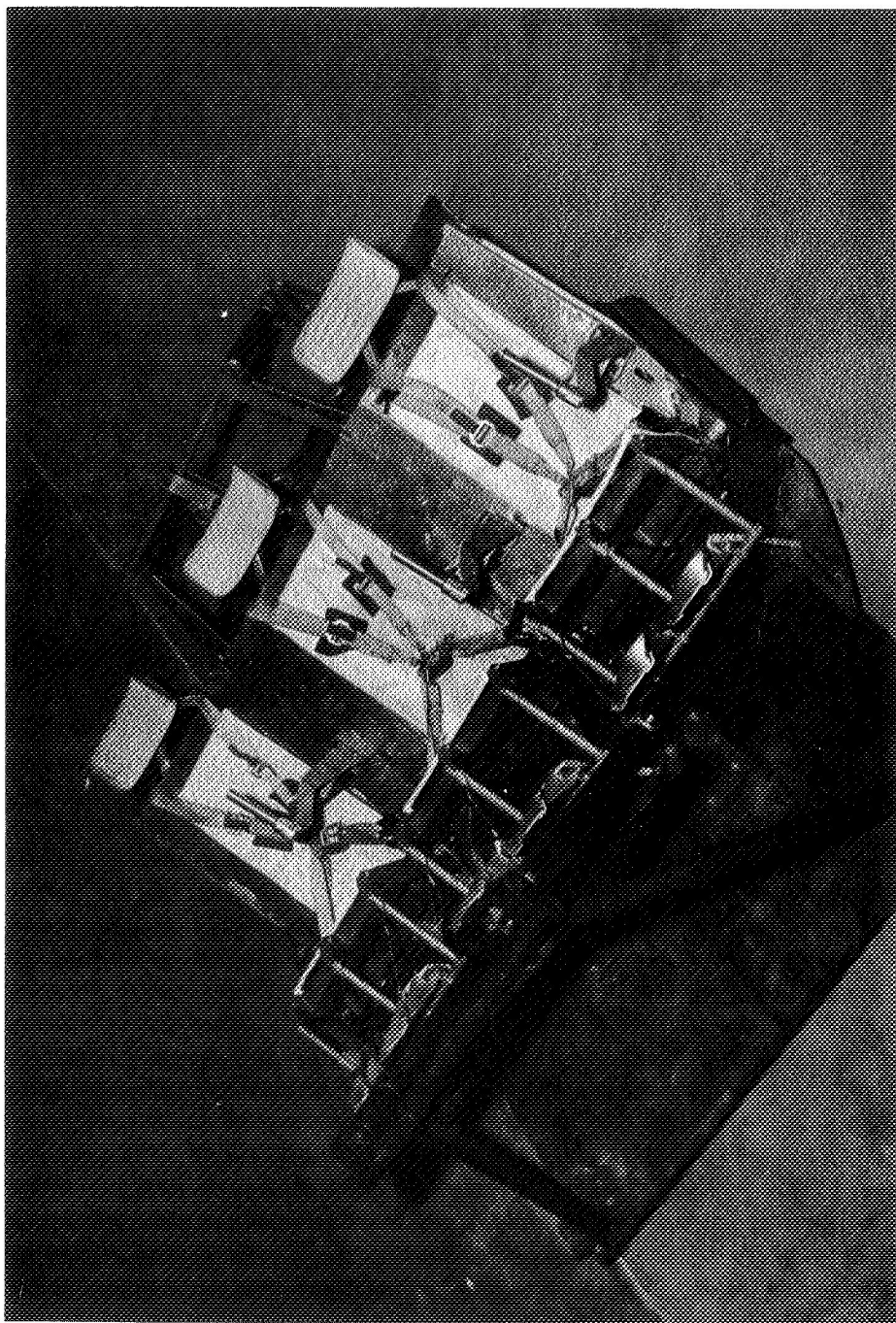
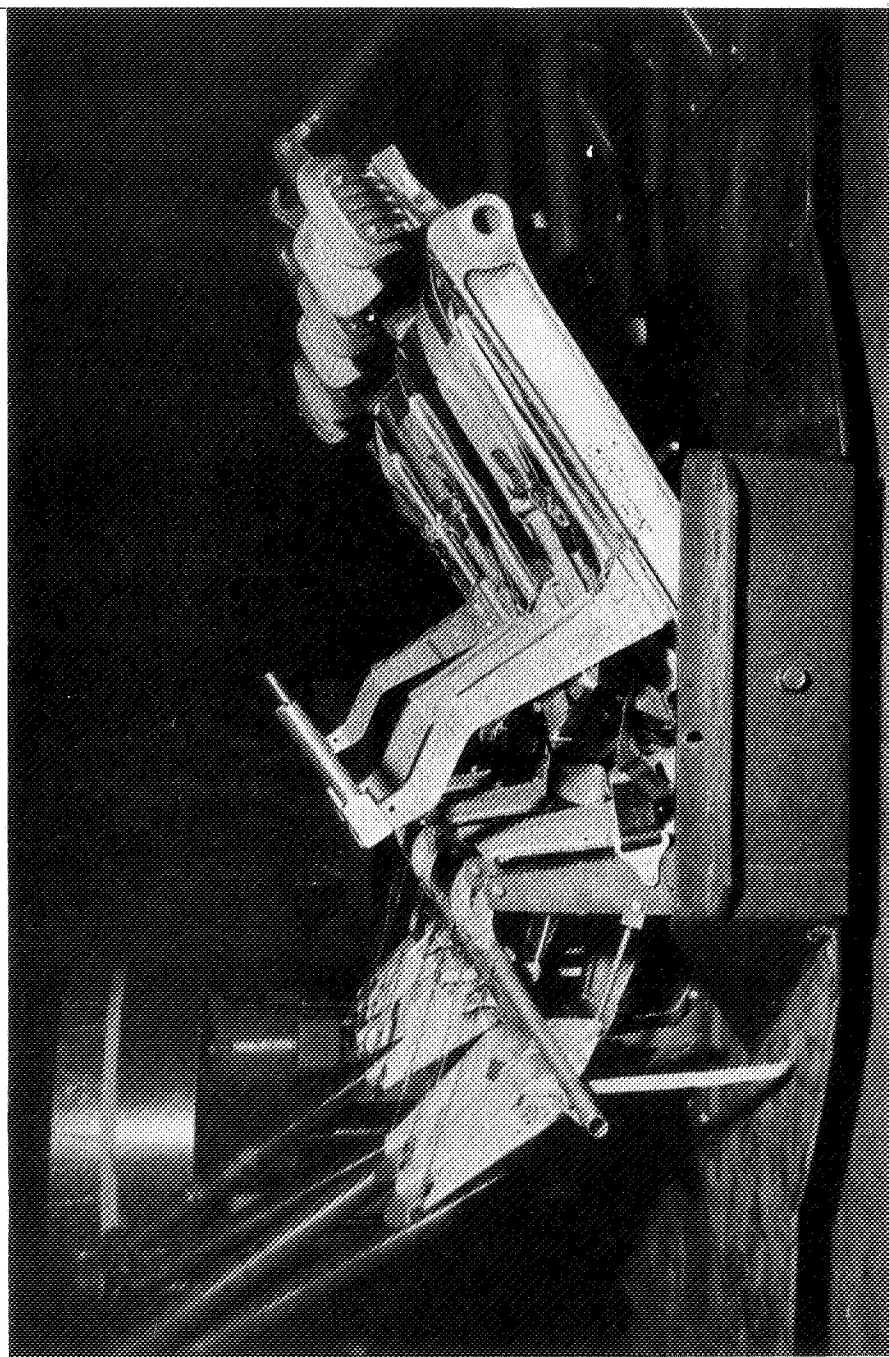


Figure 1.- Couch, restraint system and sled test fixture.  
(a) Top view.

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(b) Side view.

Figure 1. - Concluded.

NASA  
S-65-16430

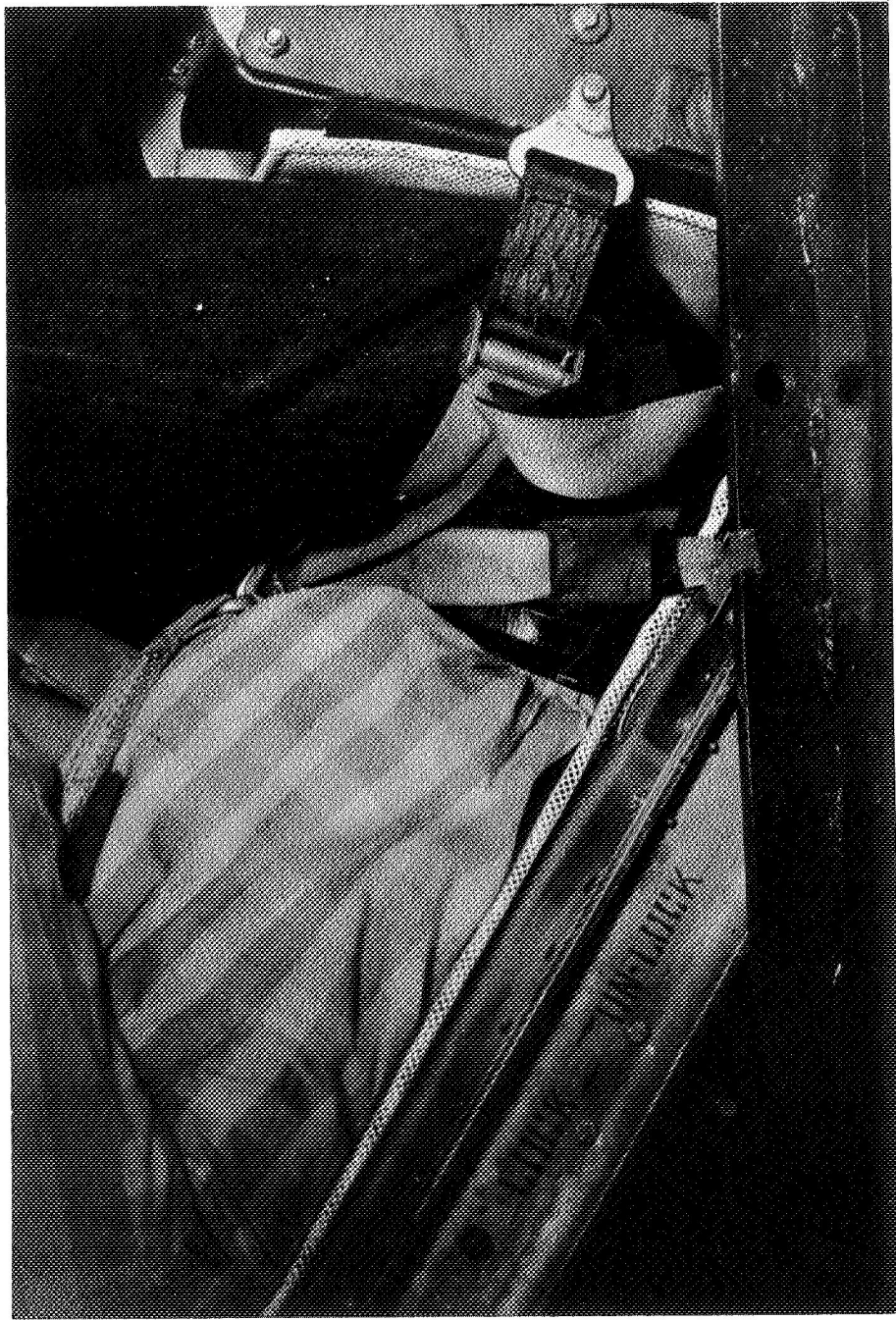
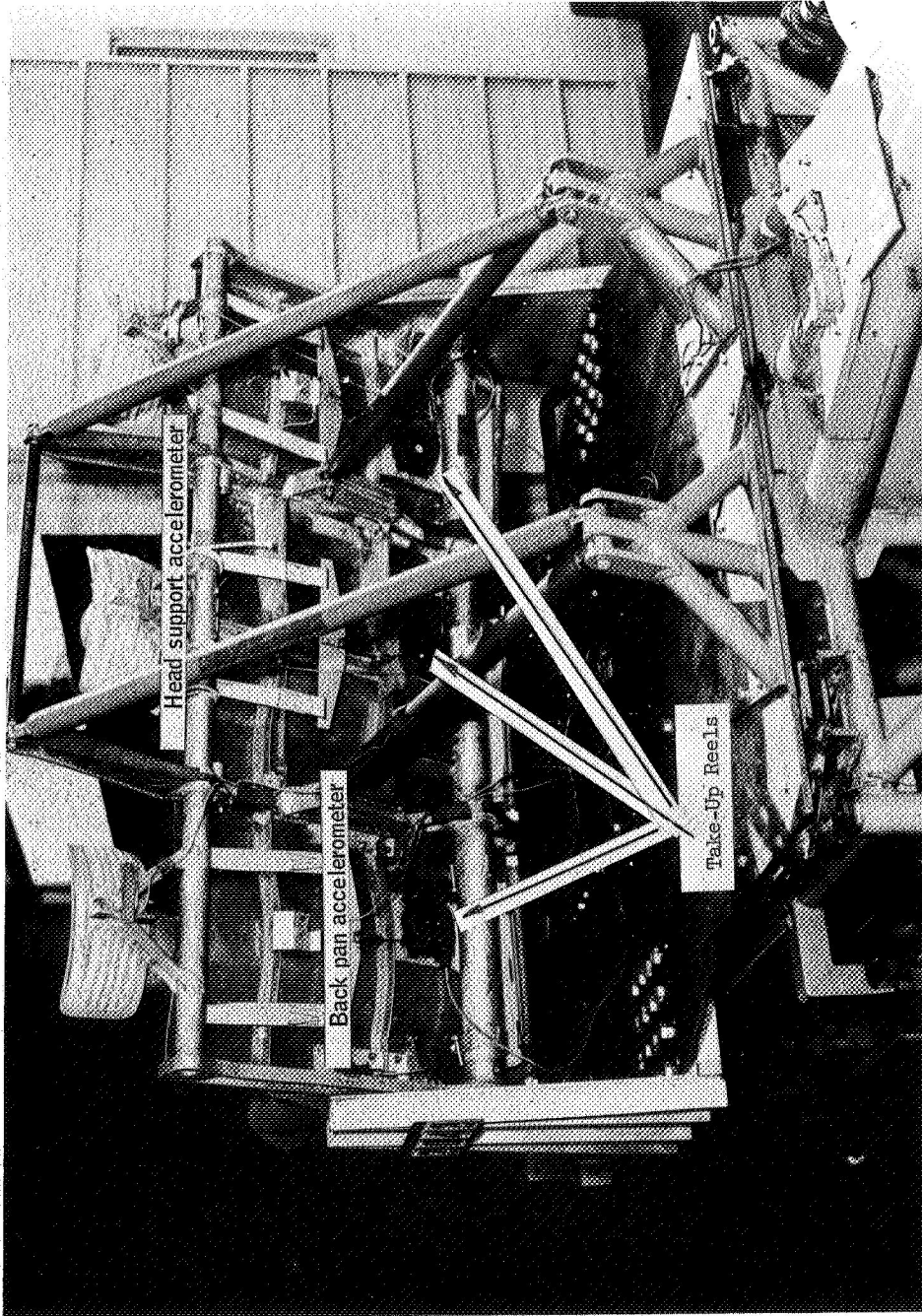


Figure 2.- Restraint harness details.  
View showing side "Y" and lap belt.

NASA

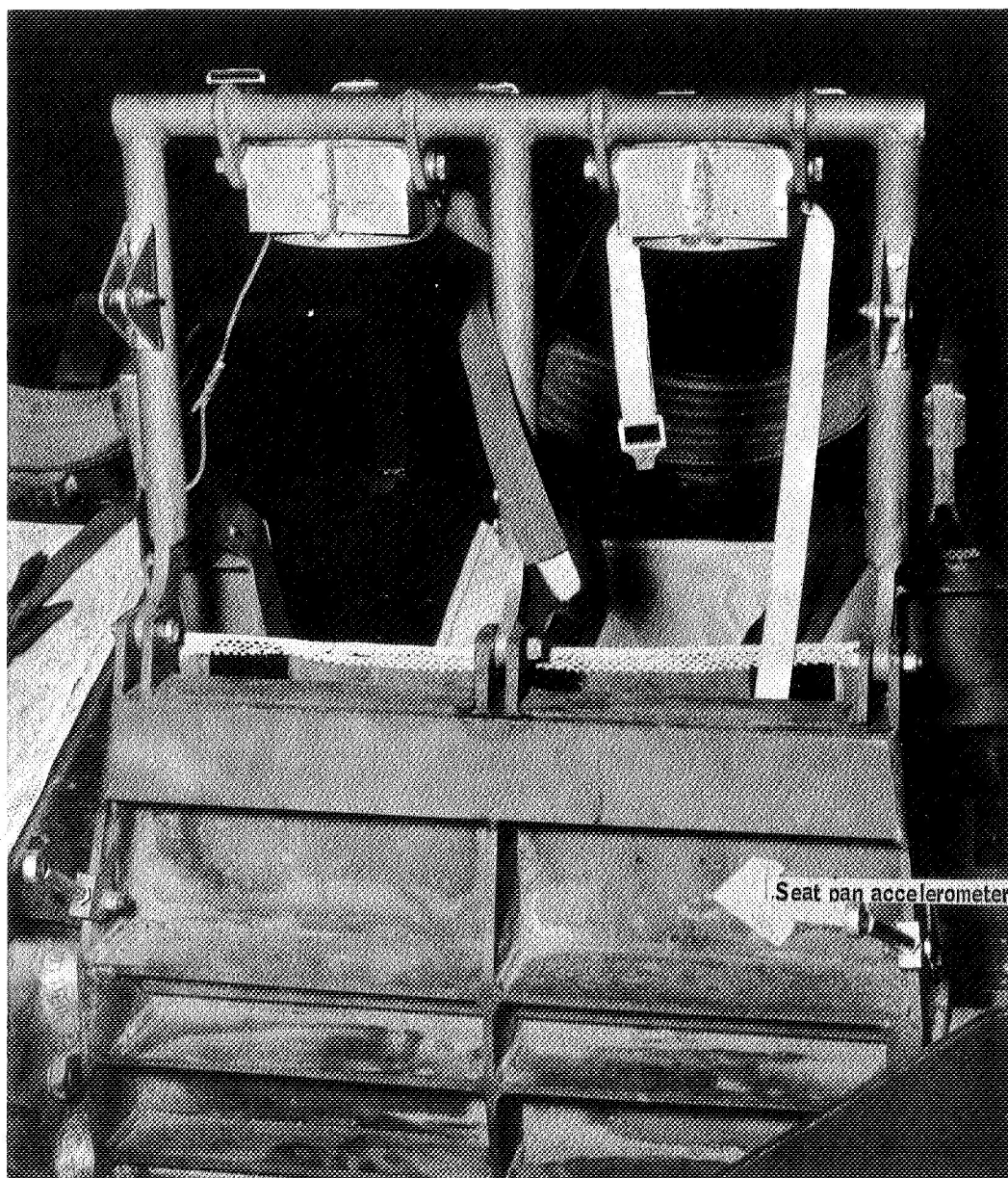
S-65-25362



(a) Head and back pan.

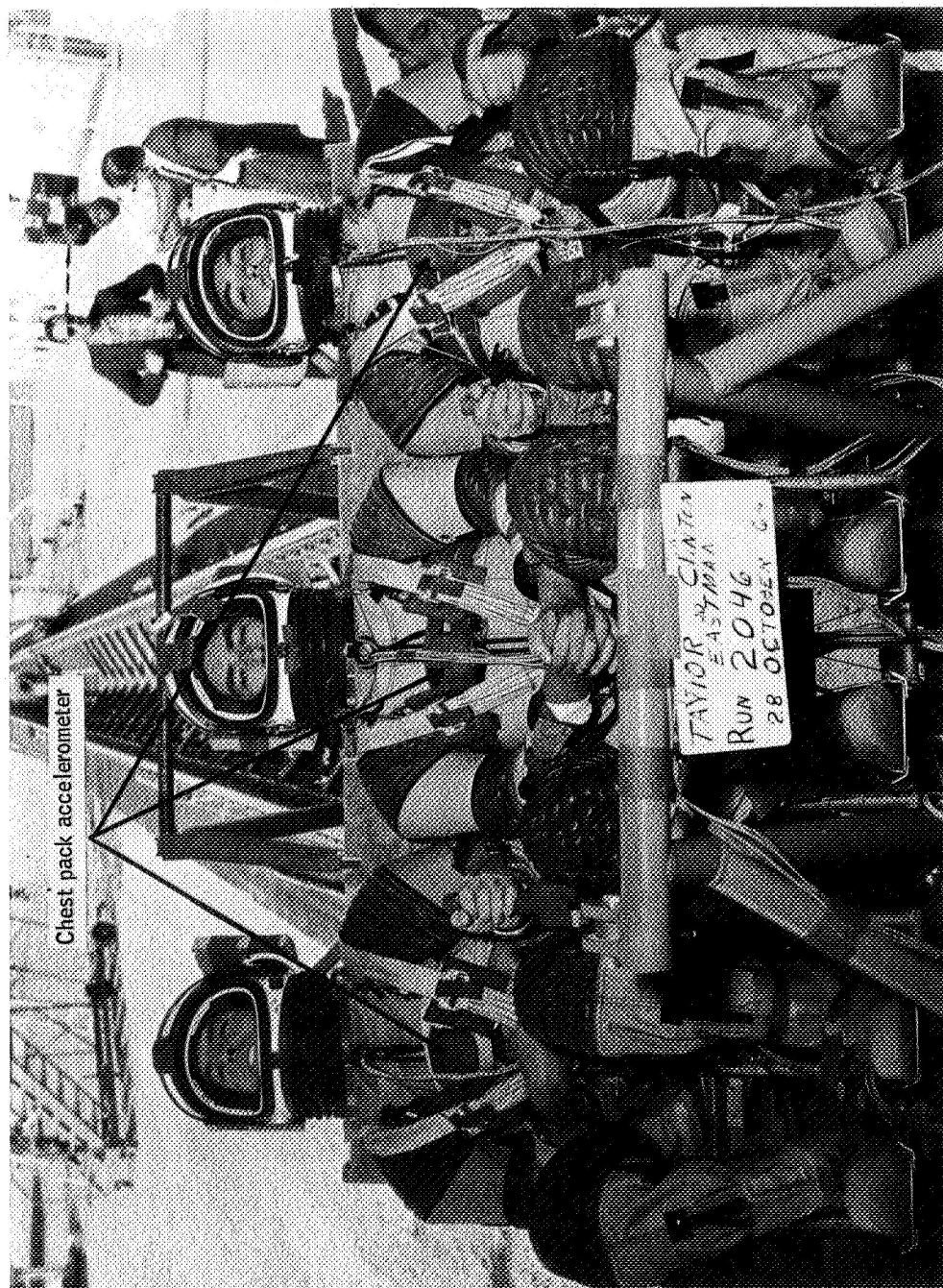
Figure 3.- Accelerometer location.





(b) Seat pan.  
Figure 3. - Continued.





(c) Chest pack accelerometer.

Figure 3. - Concluded.

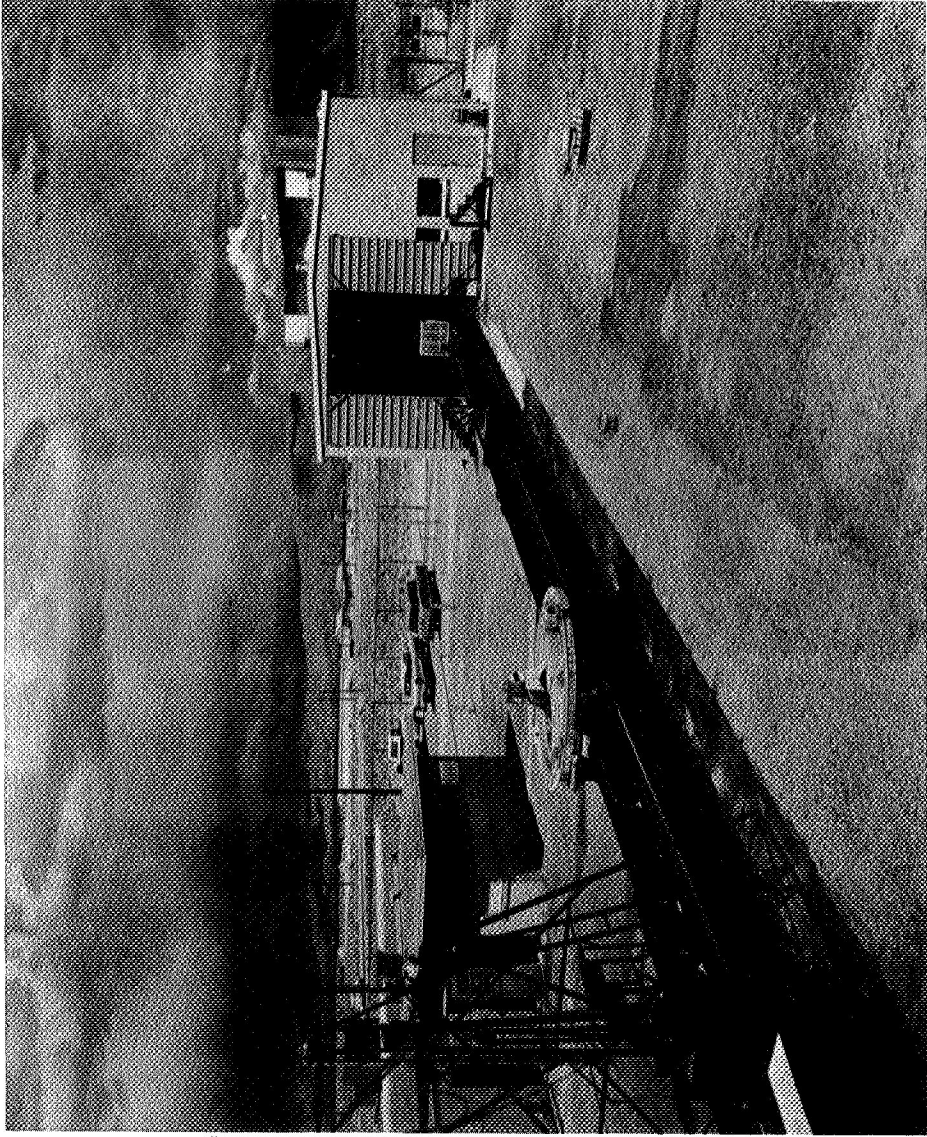


Figure 4.- Daisy decelerator facility.

Subject shown in the  
following attitude:

ROLL -  $0^\circ$   
PITCH -  $0^\circ$   
YAW -  $0^\circ$

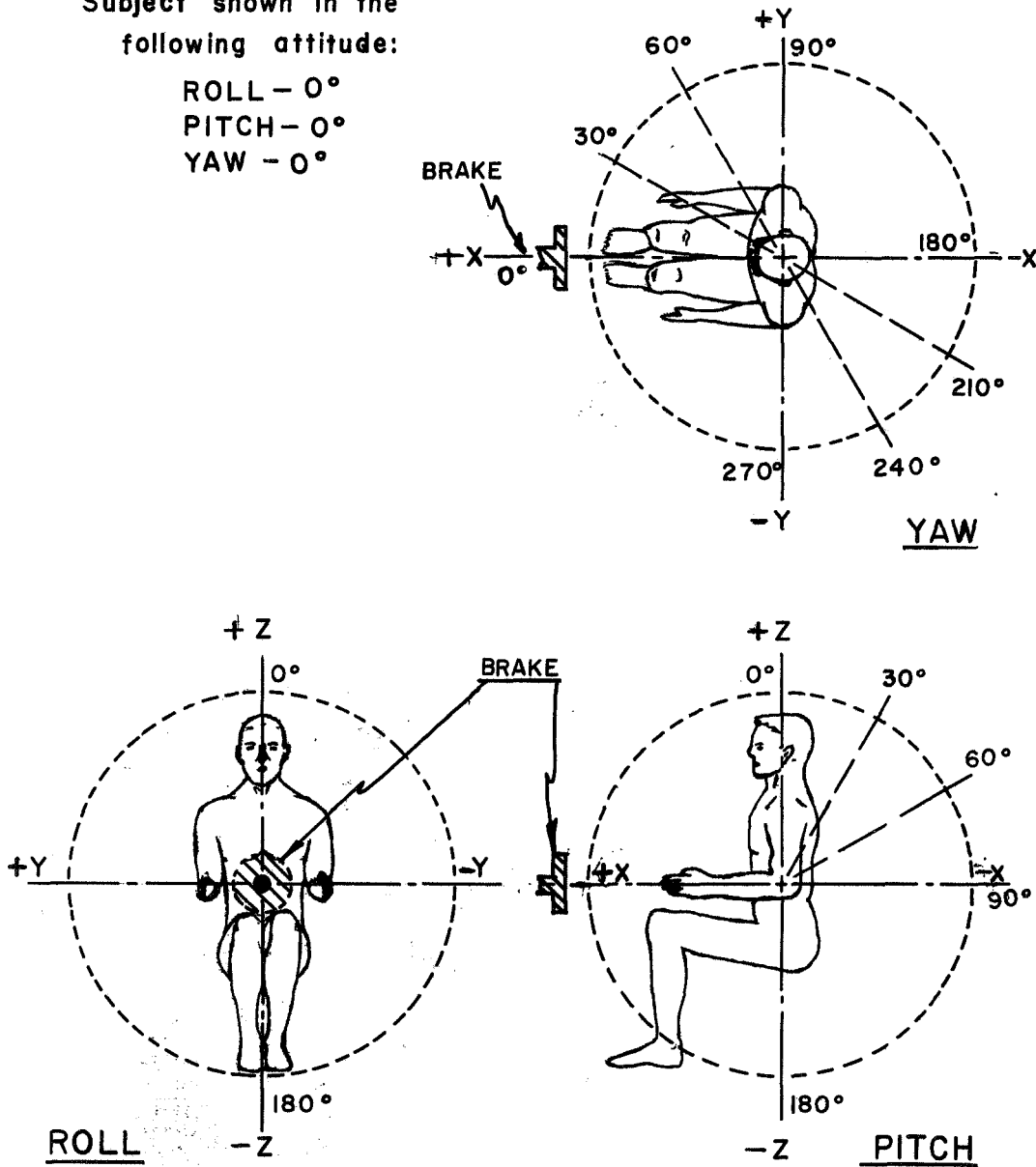
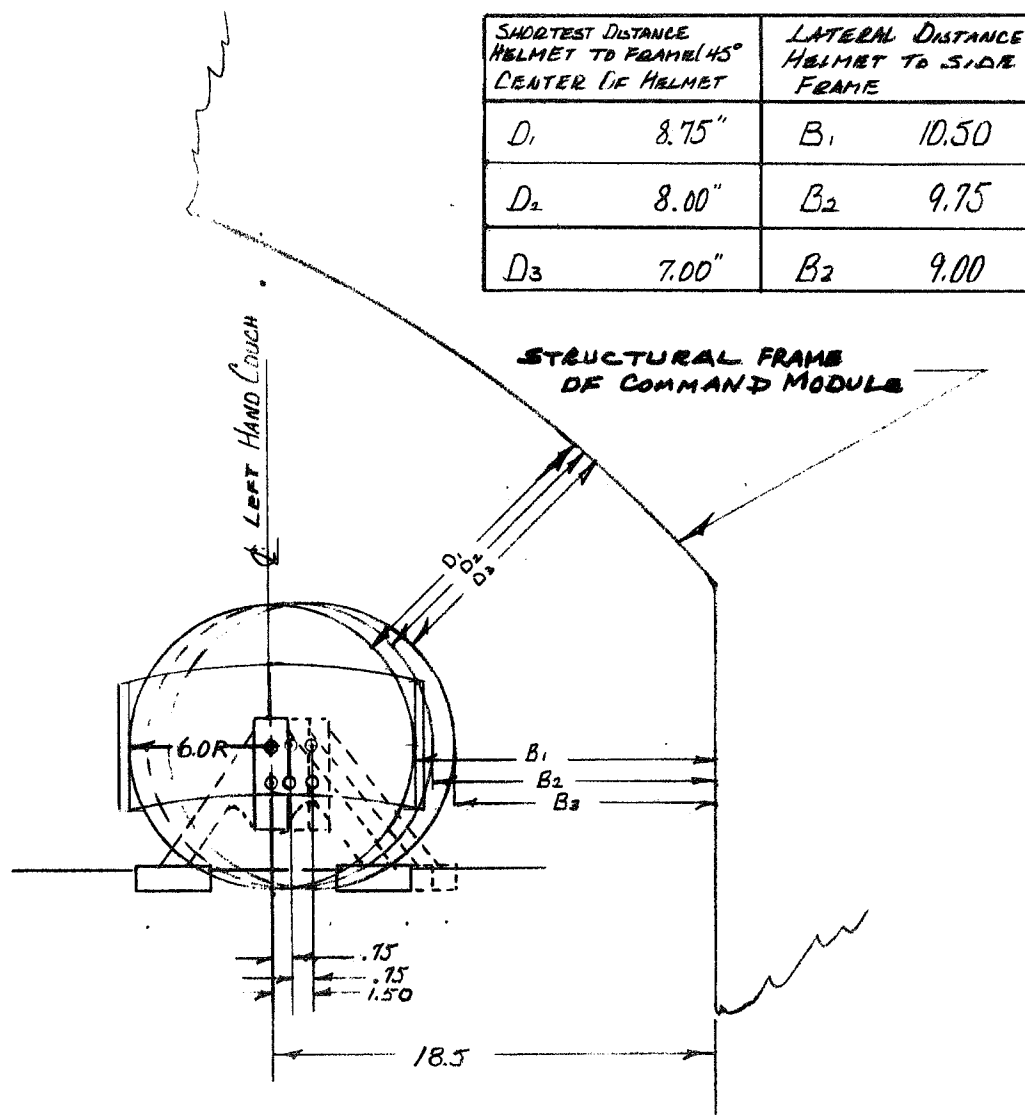


Figure 5.- position orientation.



(a) Head support and helmet location relative to side structural frame.

Figure 6. - Structural frame of command module.

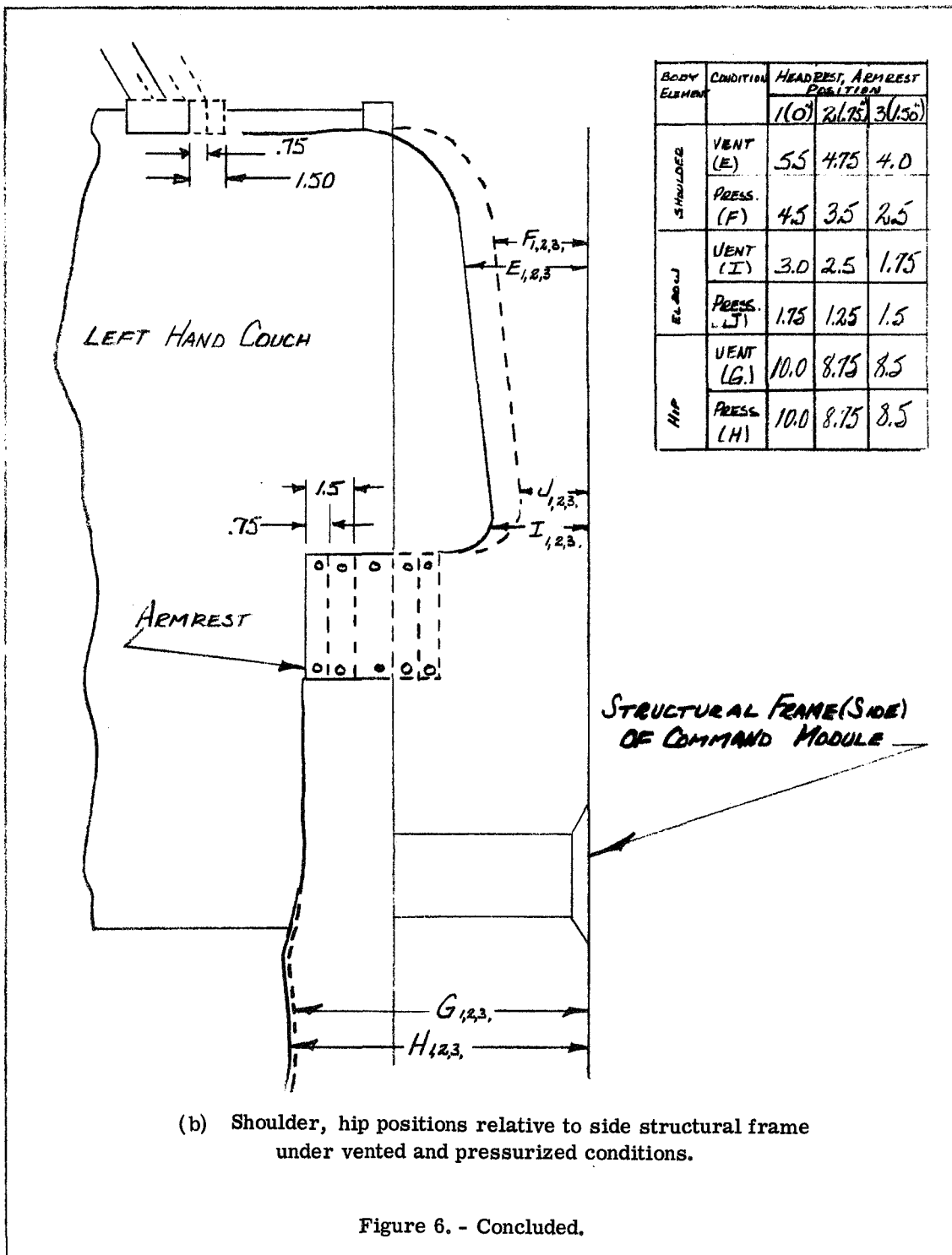


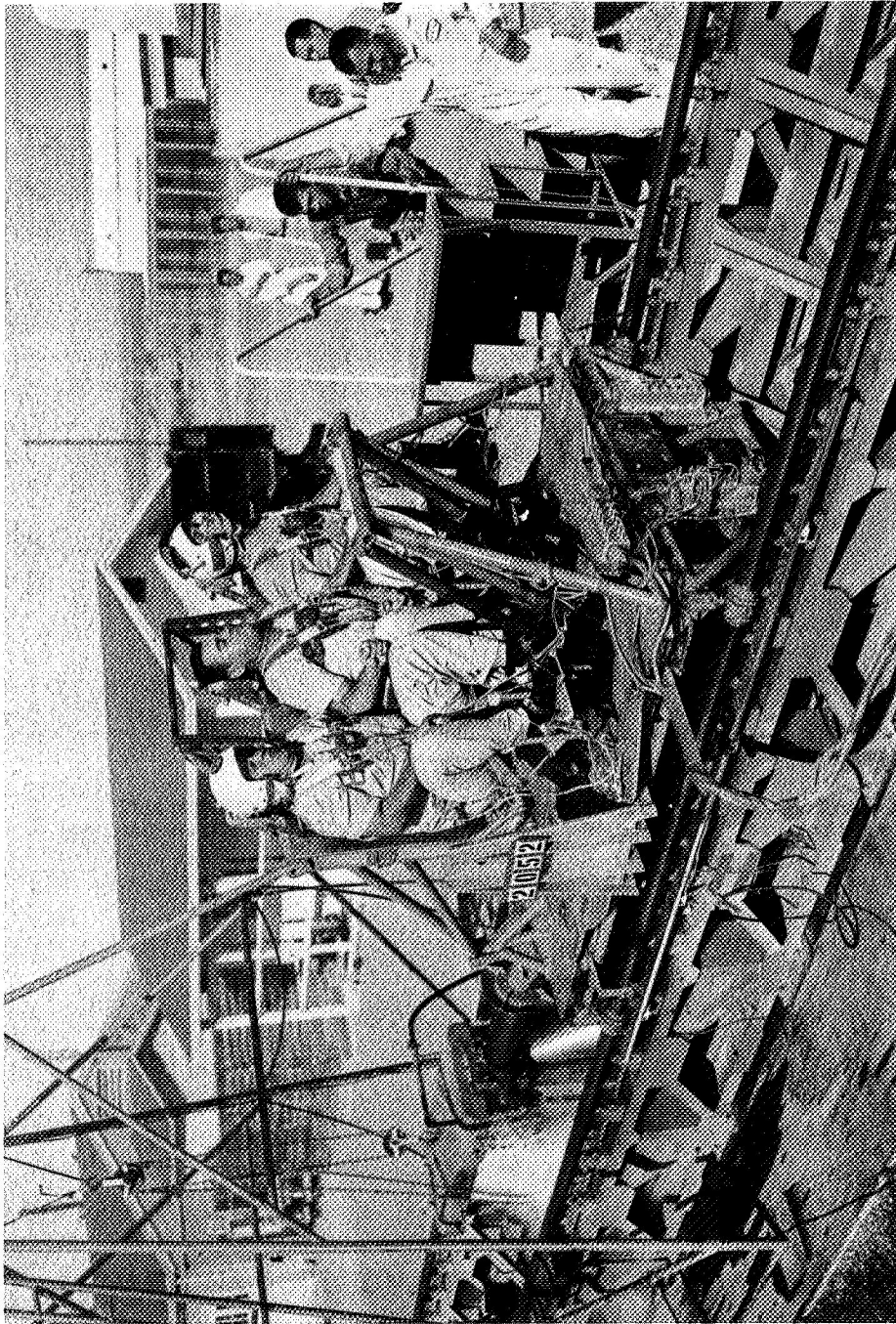


Figure 7.- Impact photographs.

(a) Lateral couch position:  $0^{\circ}$  roll,  $60^{\circ}$  pitch and  $60^{\circ}$  yaw.

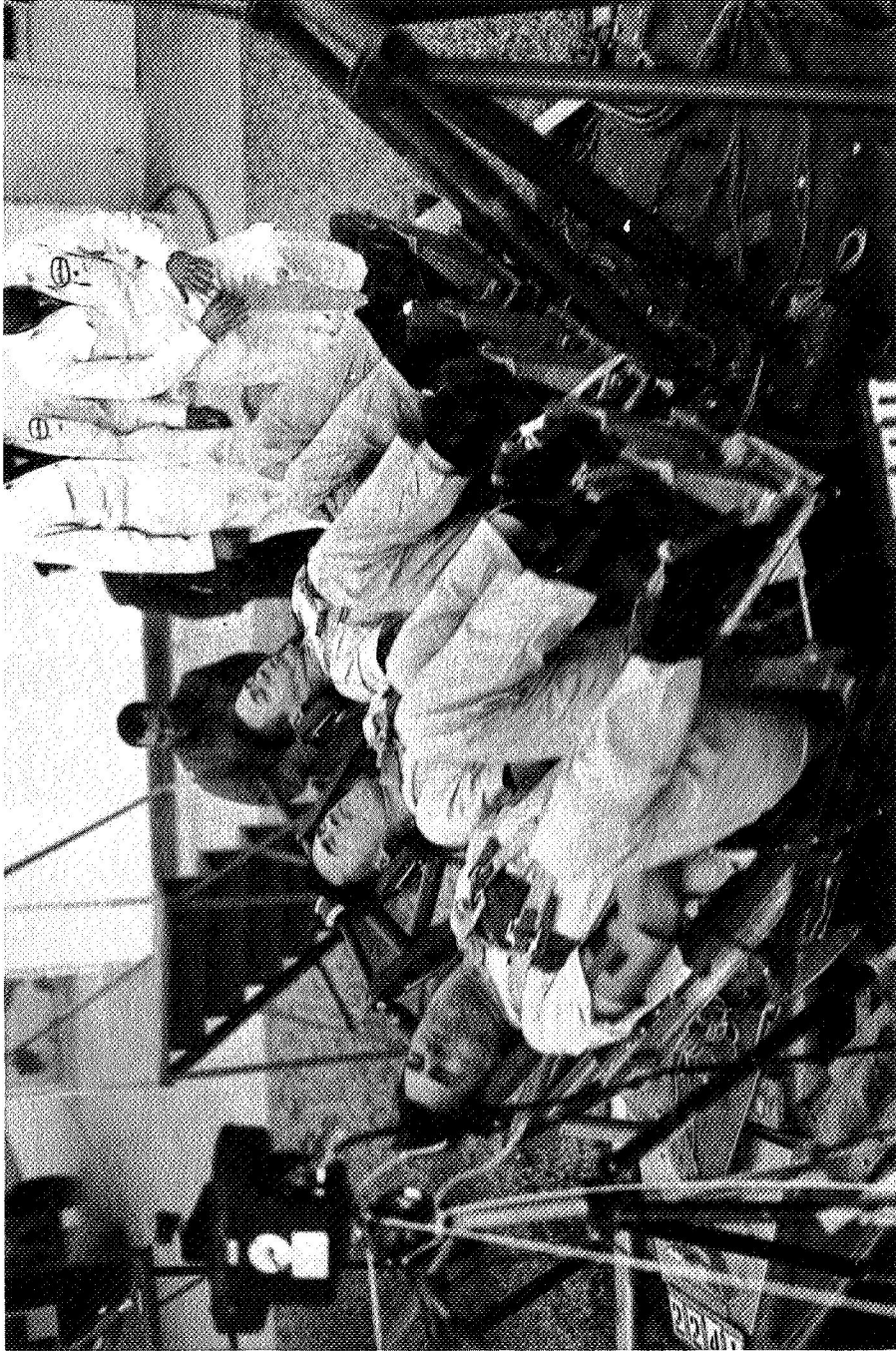
Input 12G





(b) couch position:  $0^{\circ}$  roll,  $0^{\circ}$  pitch and  $180^{\circ}$  yaw  
Input 12G.

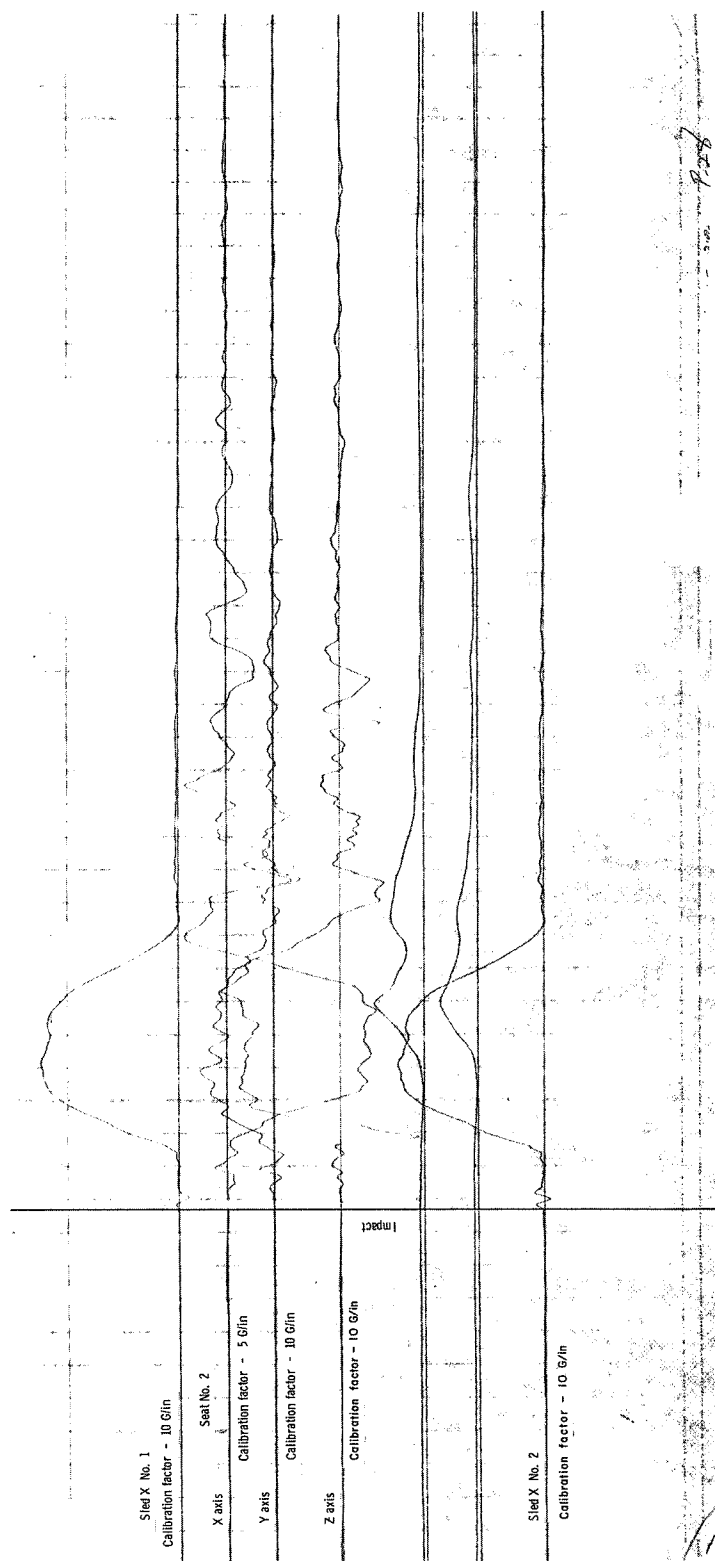
Figure 7.- Continued.



(c) Lateral couch position:  $0^{\circ}$  roll,  $60^{\circ}$  pitch and  $210^{\circ}$  yaw.  
Input 12G

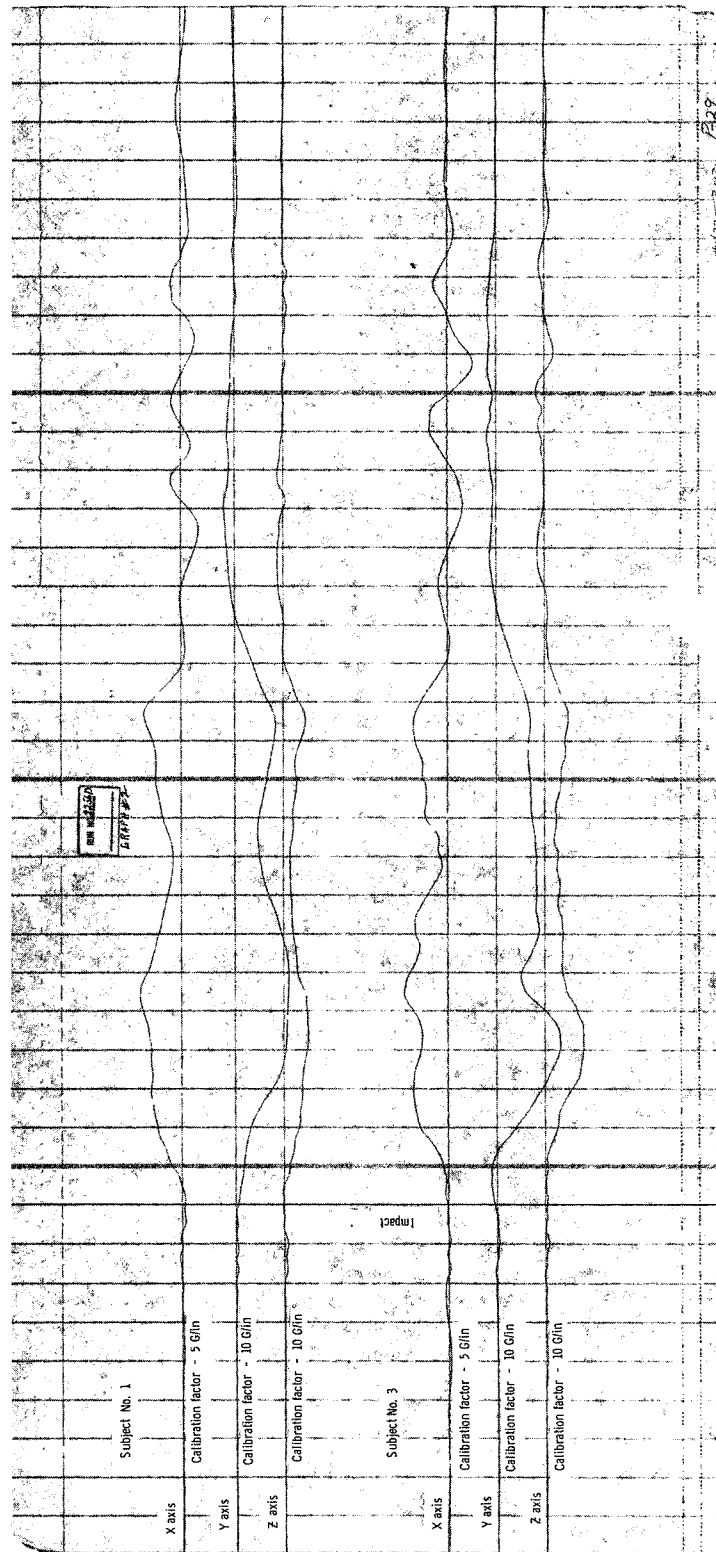
Figure 7. - Concluded.





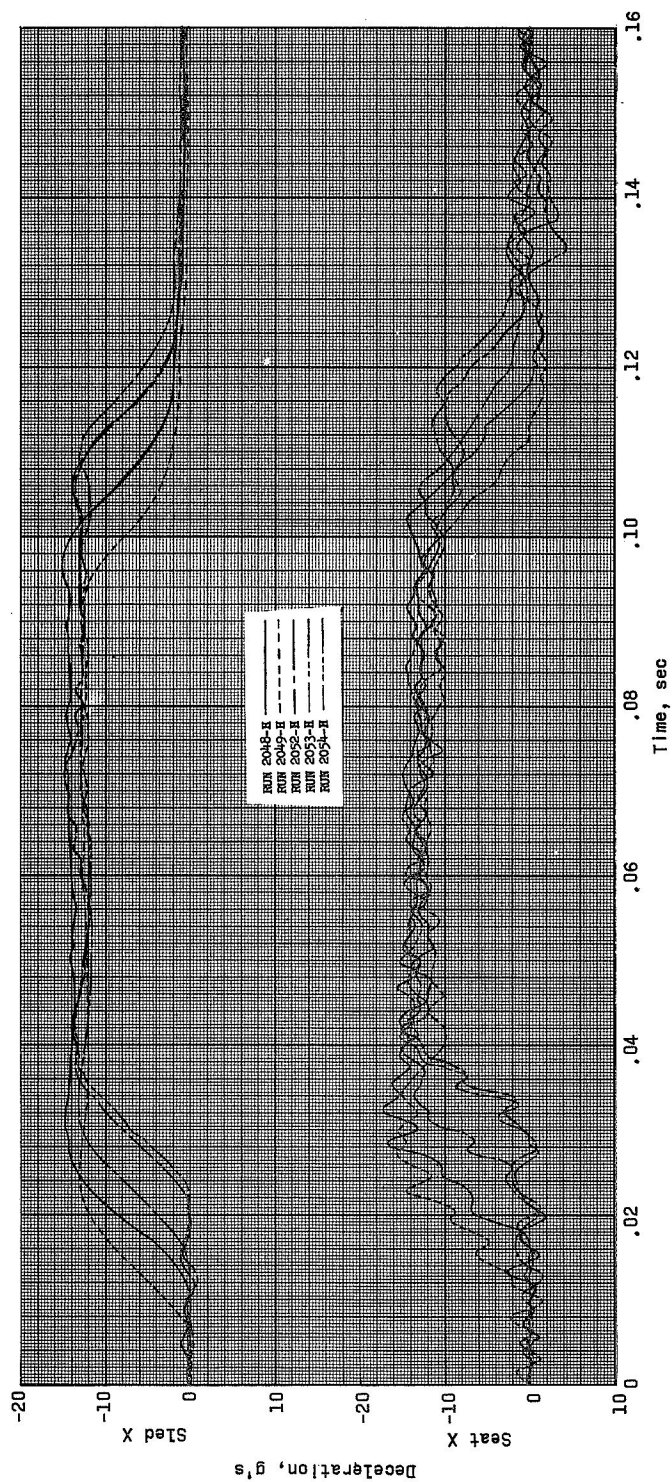
(a) Equipment

Figure 8.- Sample of recorded data.



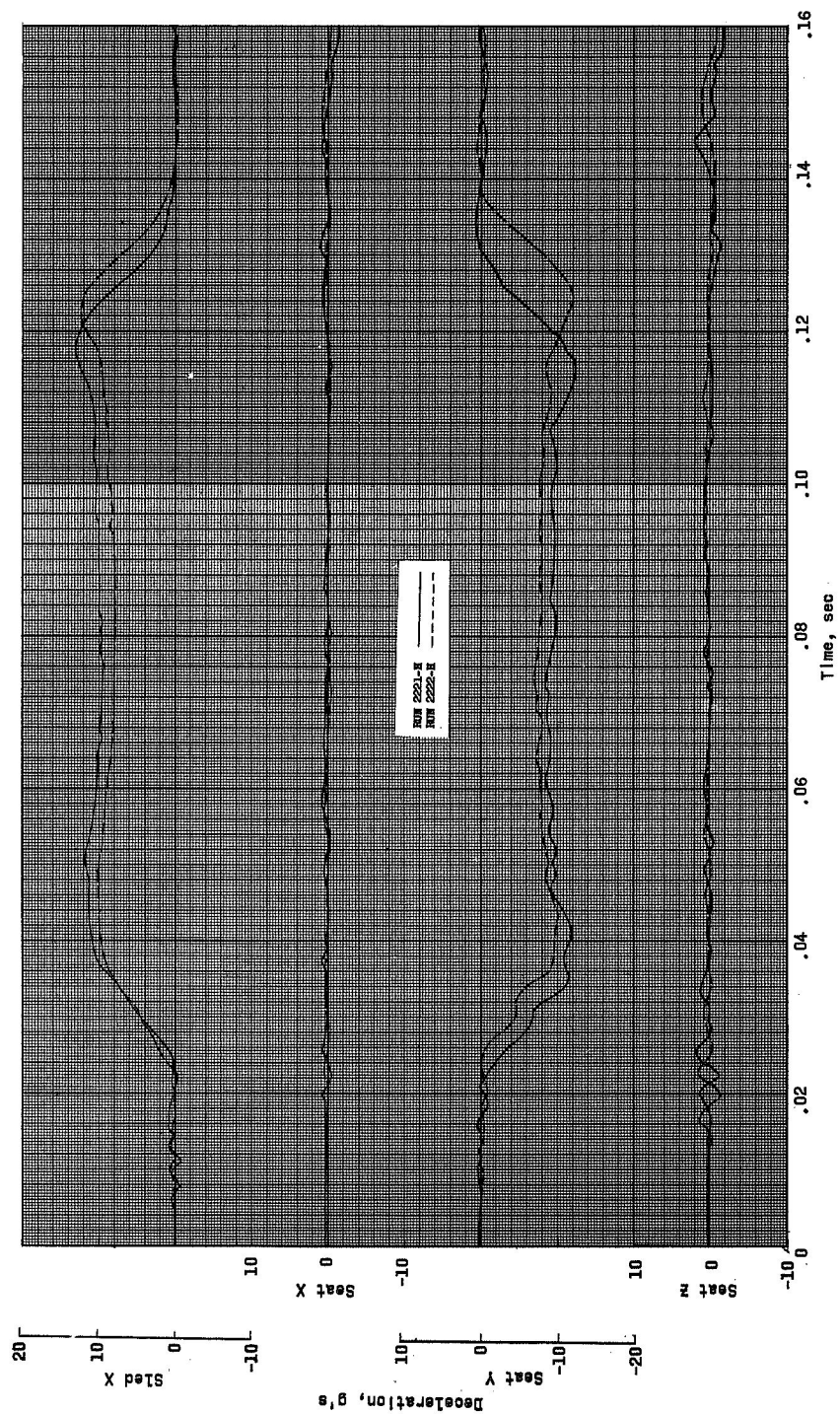
(b) Human

Figure 8.- Concluded



(a) Transverse couch position.

Figure 9.- Sled and couch deceleration time histories showing repeatability of loads.



(b) Lateral couch position: 0° roll, 60° pitch and 90° yaw.

Figure 9.- Concluded.

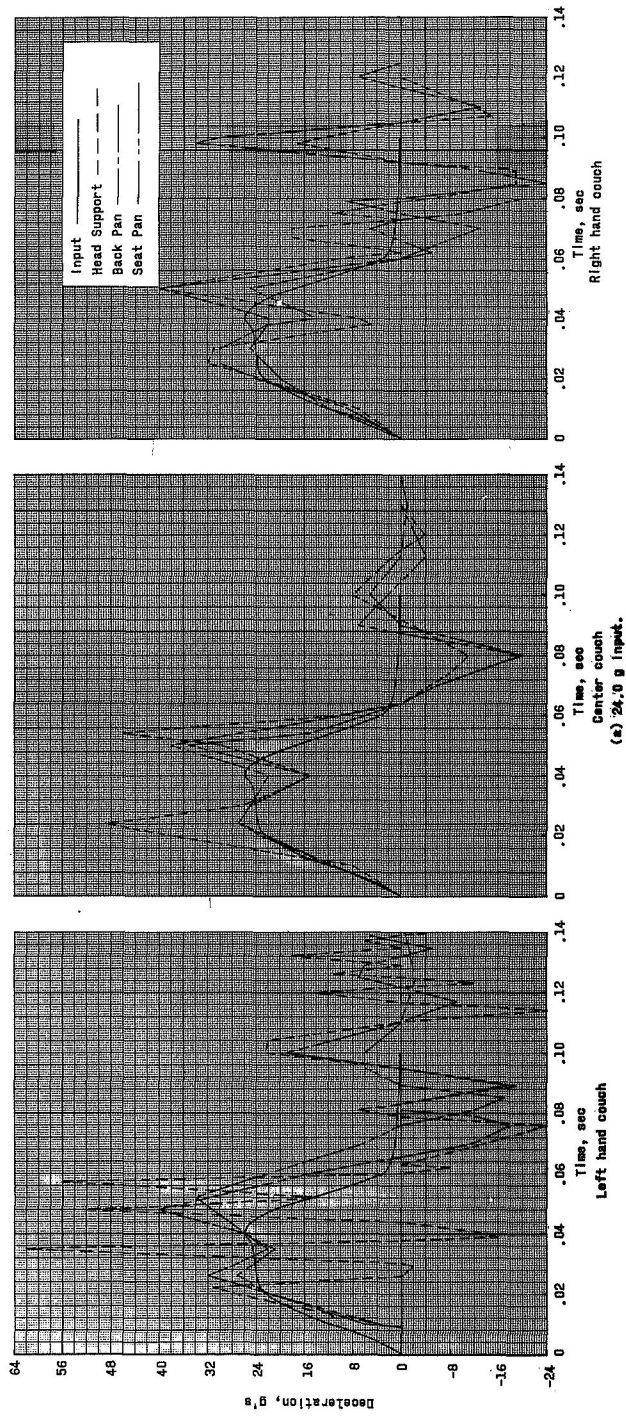
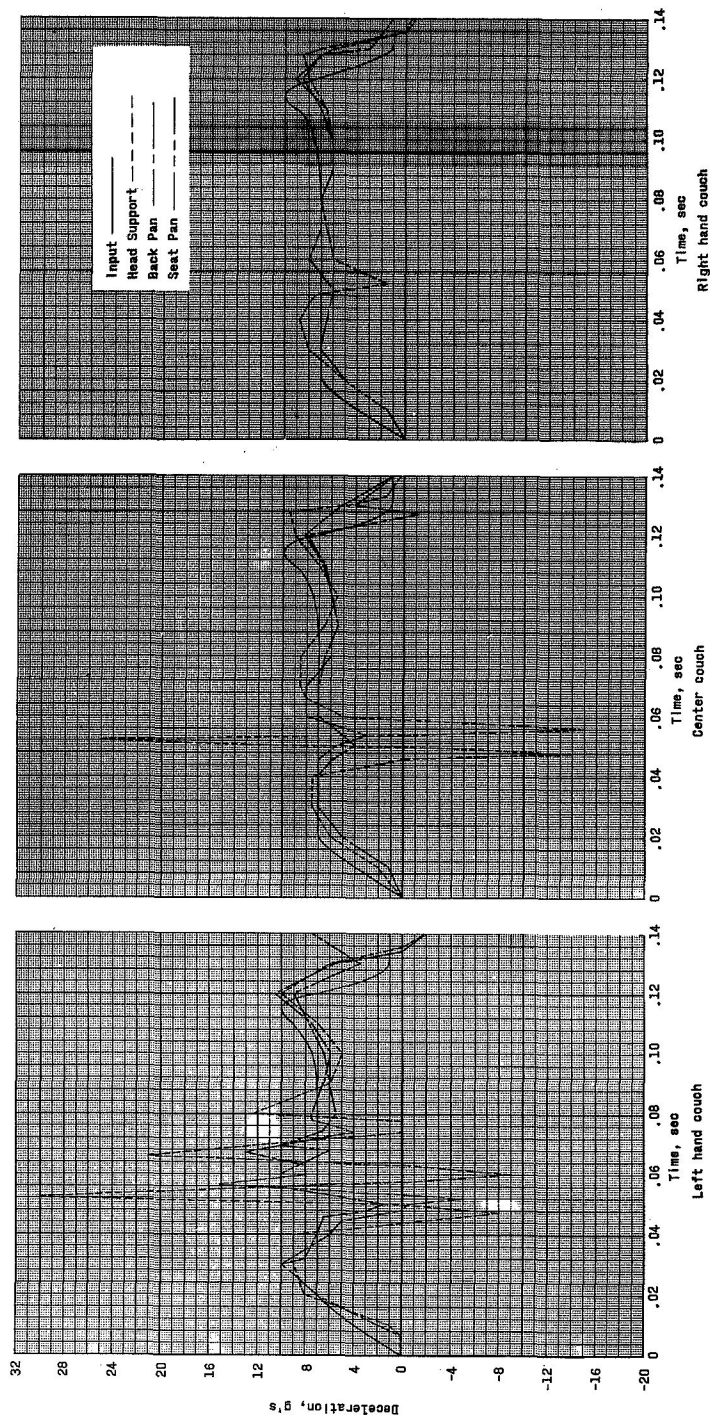


Figure 10.- Deceleration time histories showing force transmission between sled and couches; couch position:  $0^\circ$  roll,  $0^\circ$  pitch, and  $180^\circ$  yaw; couch occupants: 175 lb dummies; velocity change 37 fps.

(a) 24.0g input.

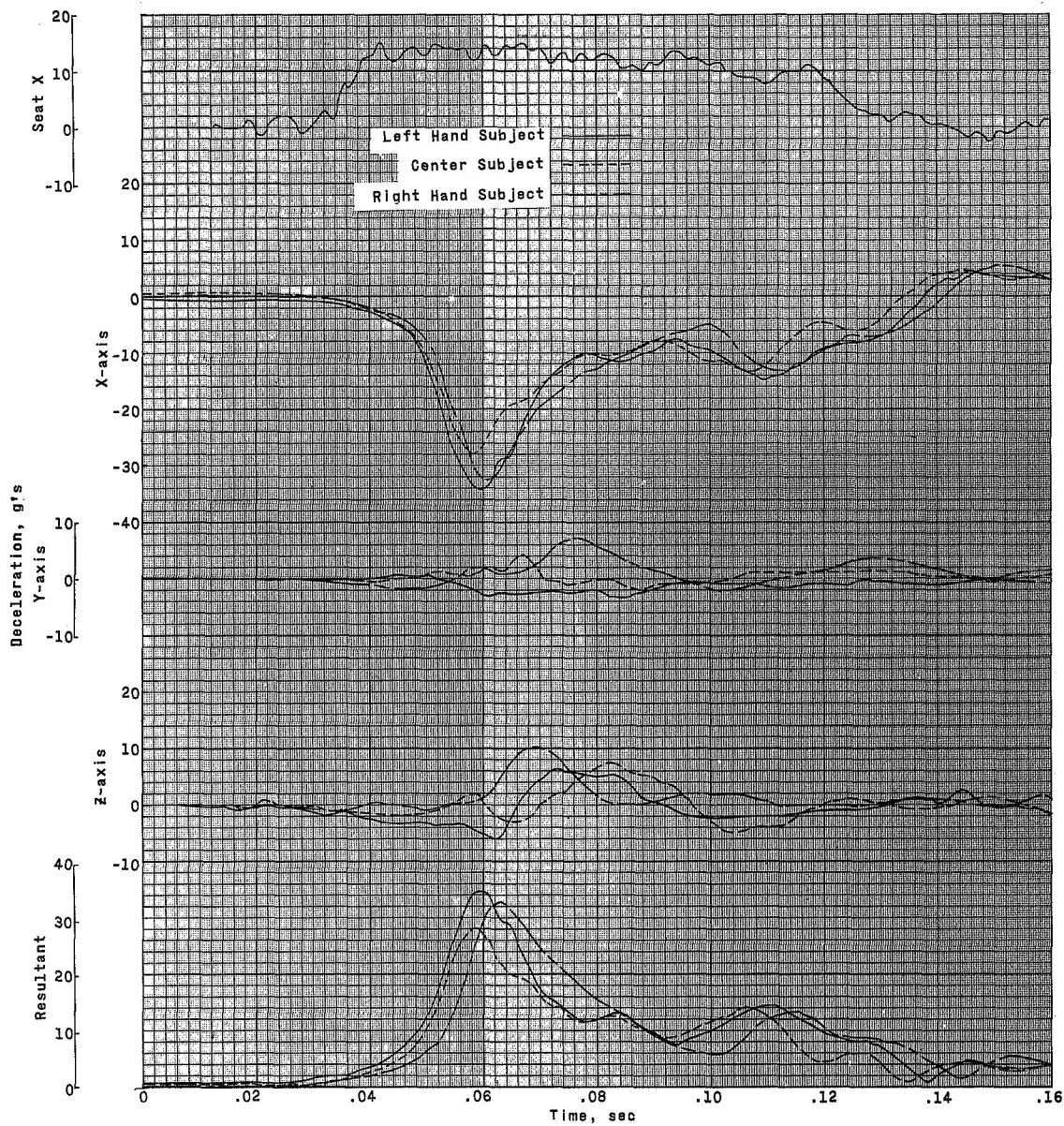
Figure 10.- Deceleration time histories showing force transmission between sled and couches; couch position:  $0^\circ$  roll,  $0^\circ$  pitch, and  $180^\circ$  yaw; couch occupants: 175 lb dummies; velocity change 37 fps.



(b) 7.5g input.

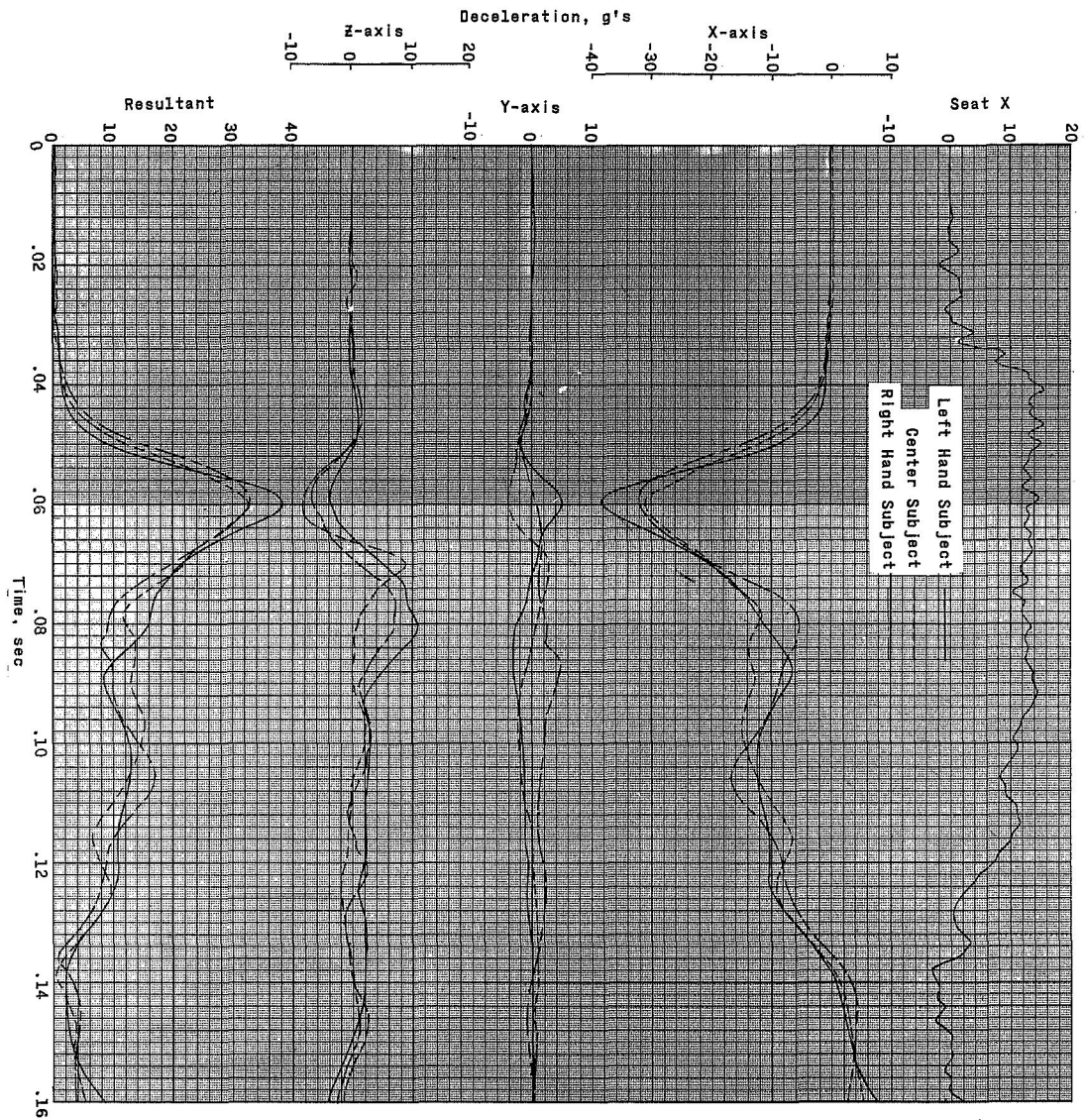
Figure 10.- Concluded.





(a) Couch occupant weight plus suit, 165 lbs.

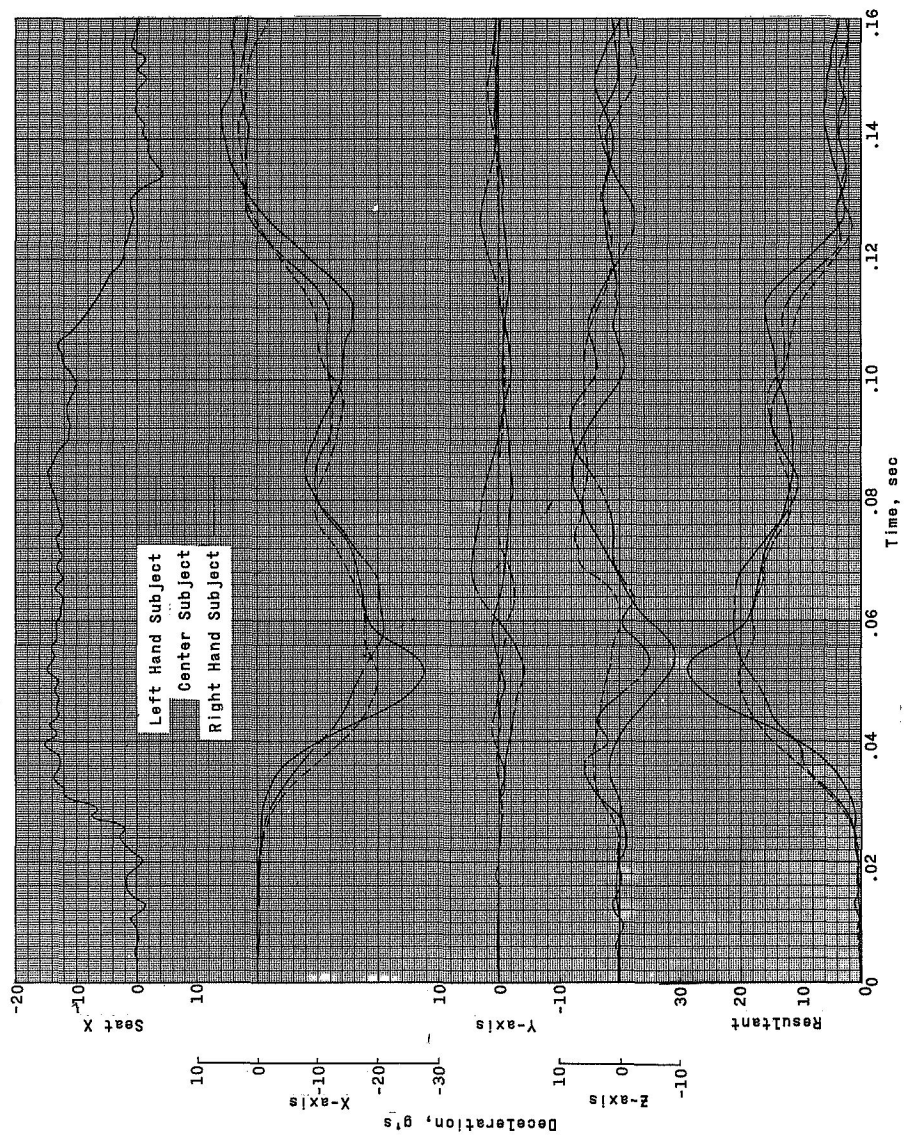
Figure 11.- Comparison of left hand, center and right hand couch occupants deceleration time histories; couch position:  $0^\circ$  roll,  $0^\circ$  pitch and  $180^\circ$  yaw; velocity change 37 fps.



(b) Couch occupant weight plus suit, 190 lbs.

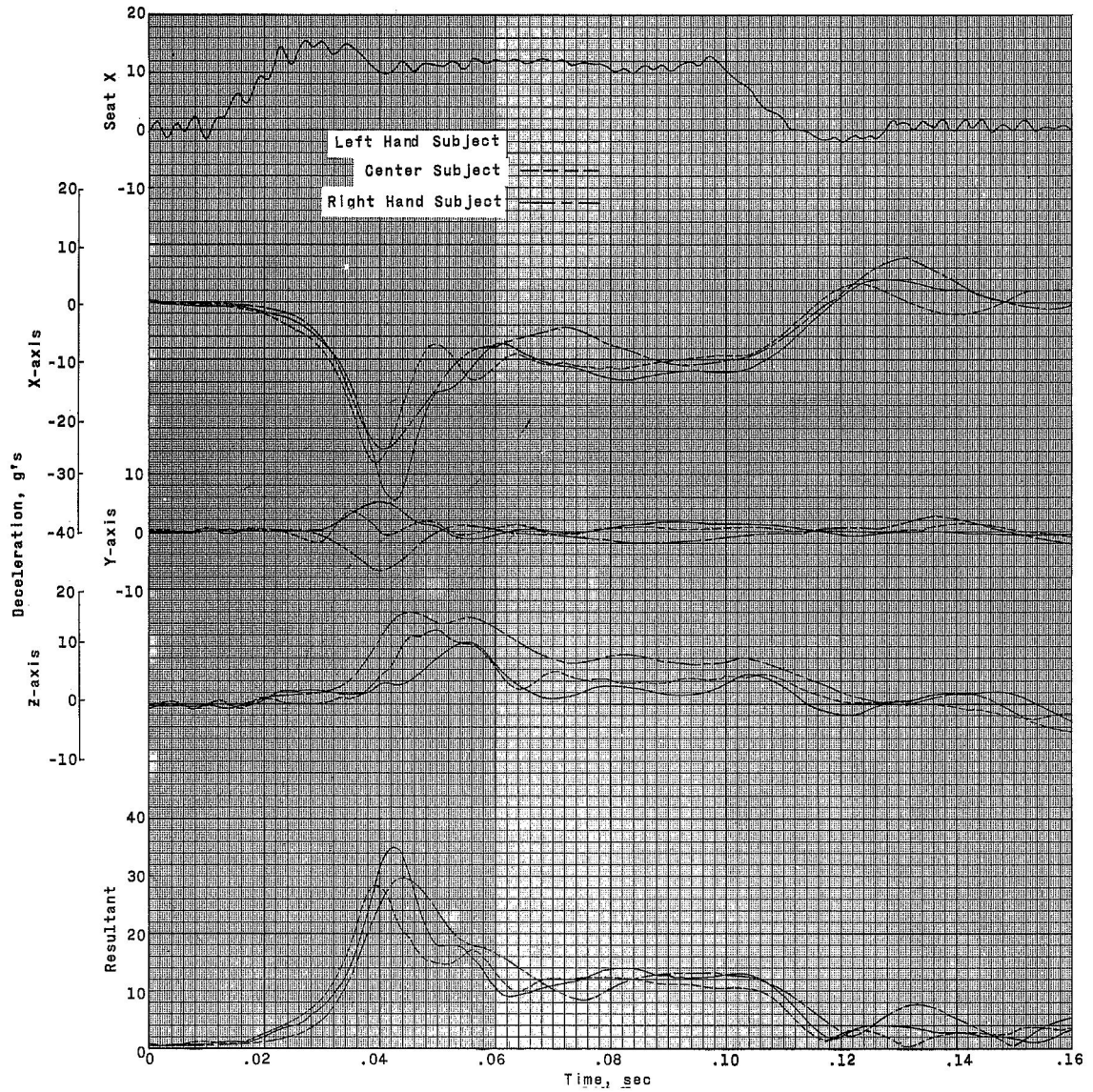
Figure 11.- Continued.





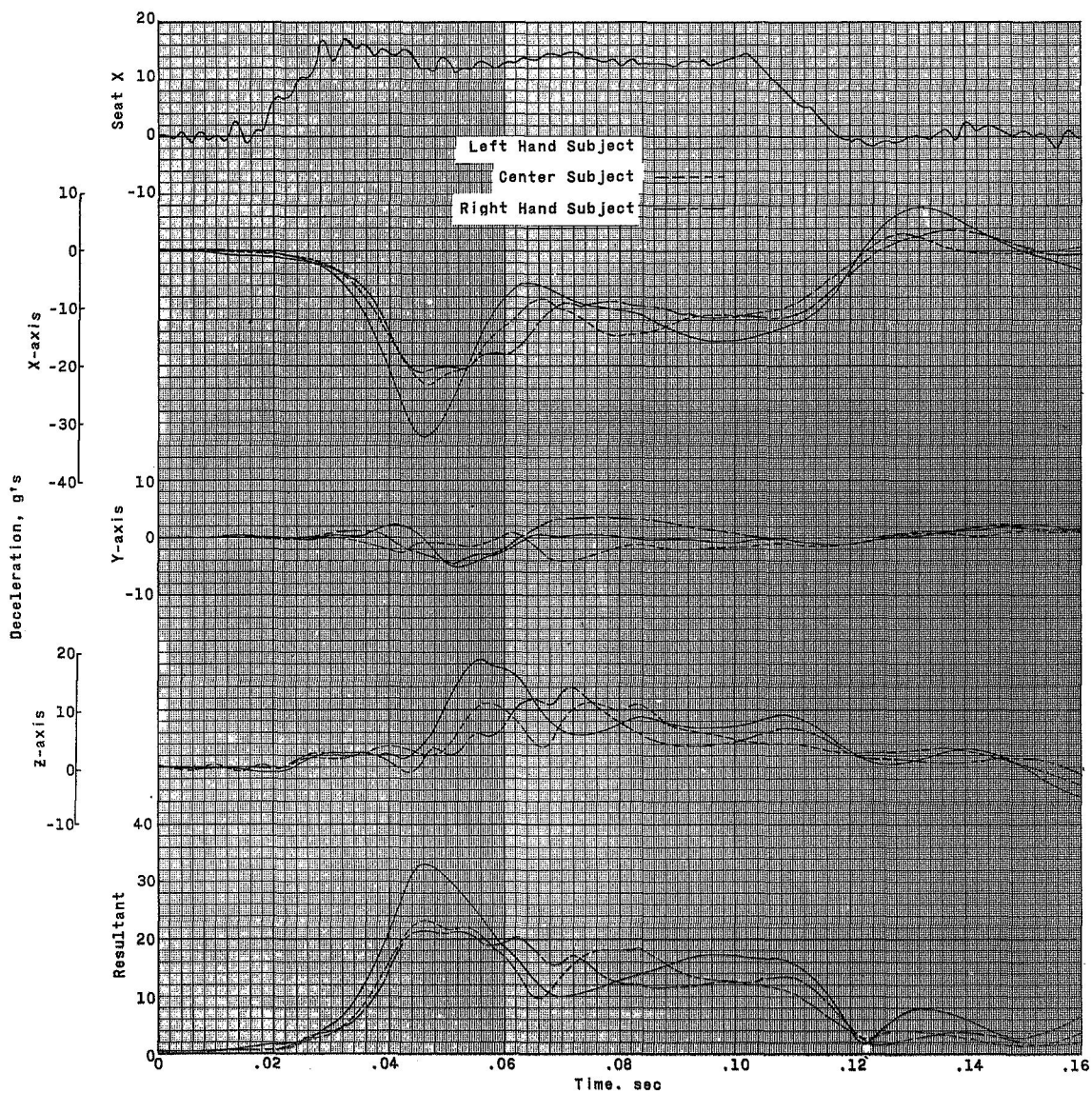
(c) Couch occupant weight plus suit, 215 lbs.

Figure 11.- Concluded.



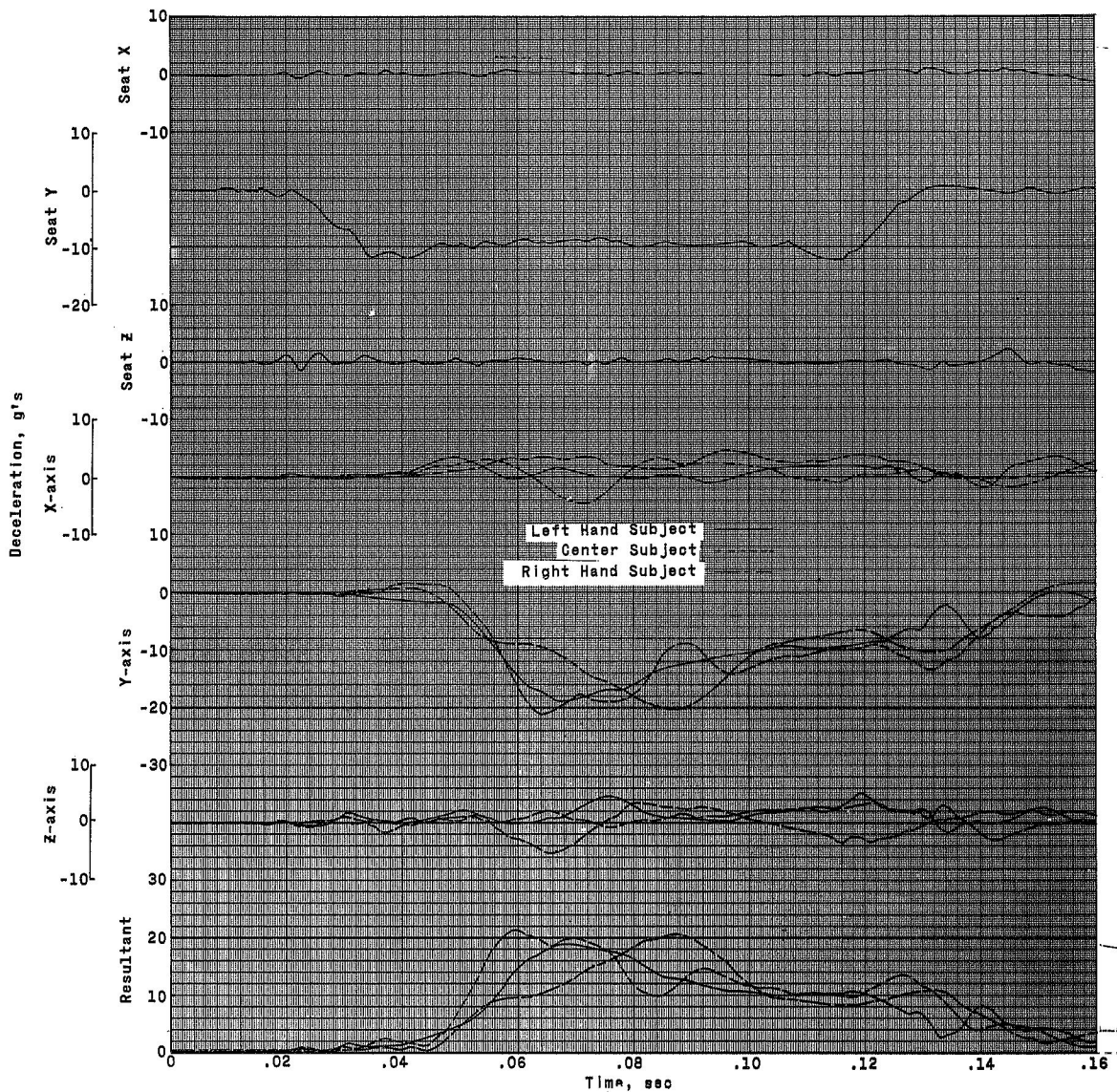
(a) Couch occupant weight plus suit, 165 lbs.

Figure 12.- Comparison of left hand, center and right hand couch occupants deceleration time histories; couch position:  $0^\circ$  roll,  $30^\circ$  pitch and  $180^\circ$  yaw; velocity change 37 fps.



(b) Couch occupant weight plus suit, 190 lbs.

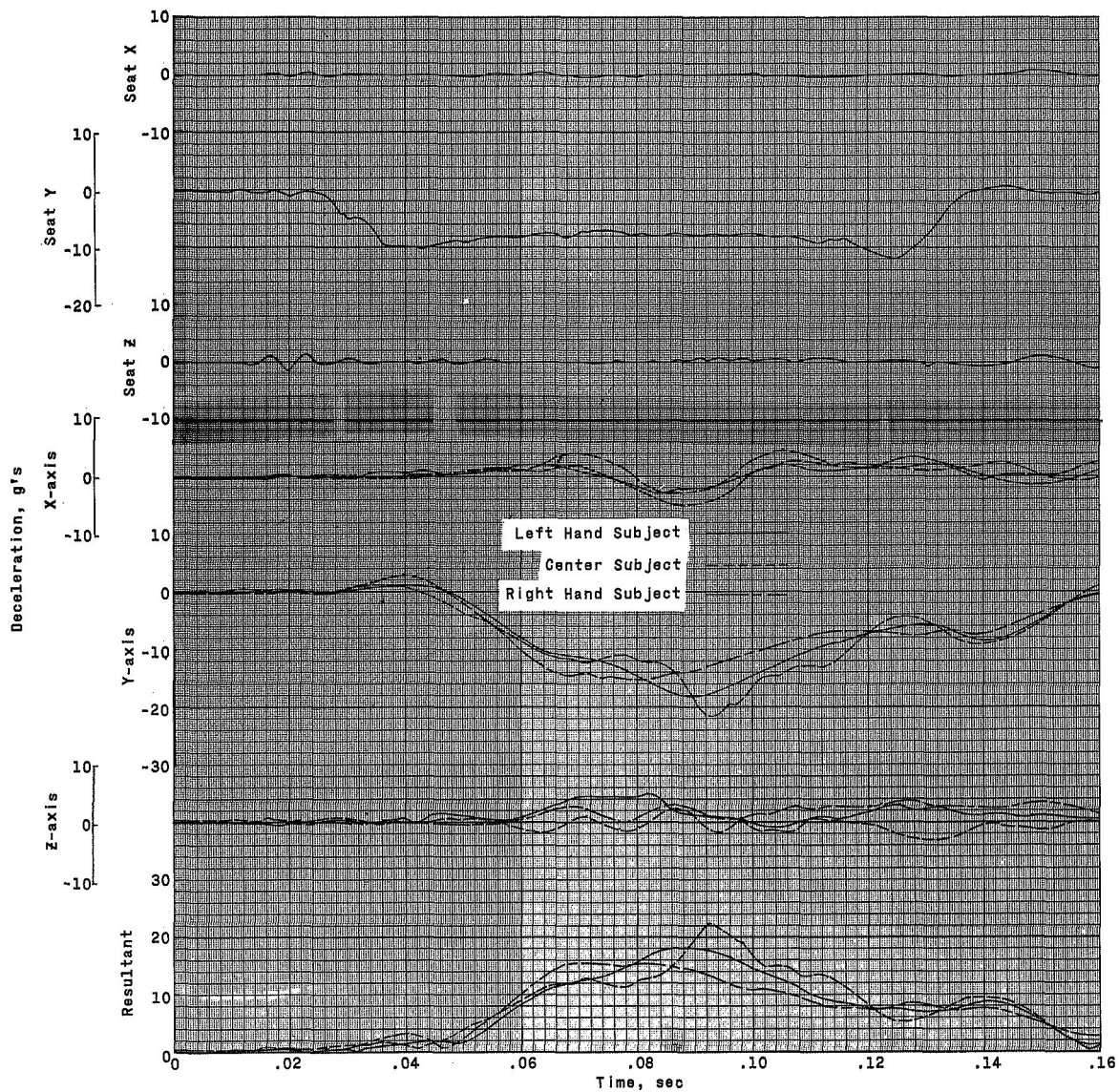
Figure 12.- Concluded.



(a) Couch occupant weight plus suit, 165 lbs.

Figure 13.- Comparison of left hand, center and right hand couch occupants deceleration time histories; couch position:  $0^\circ$  roll,  $60^\circ$  pitch and  $90^\circ$  yaw; velocity change 37 fps.





(b) Couch occupant weight plus suit, 190 lbs.

Figure 13.- Concluded.

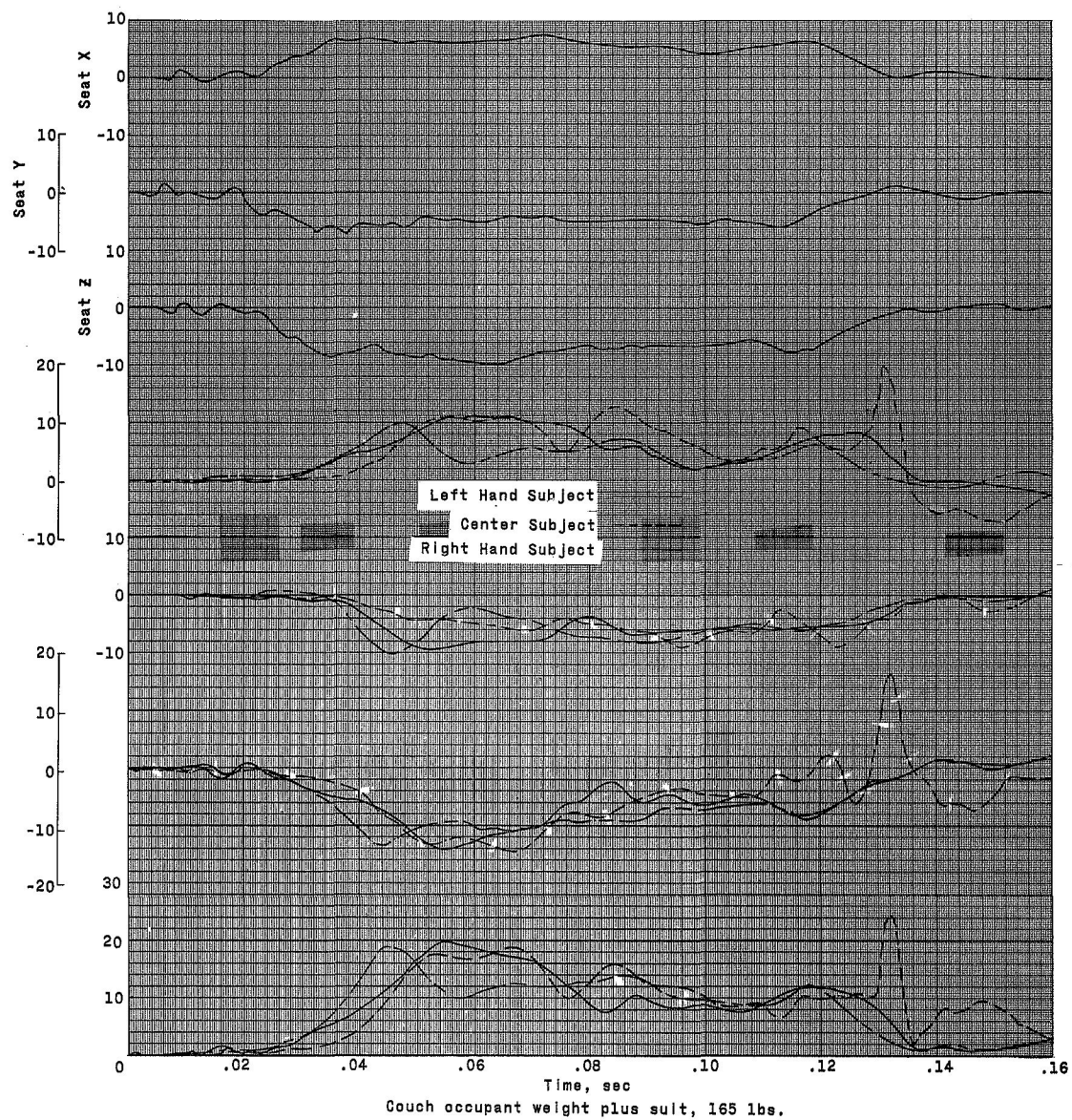
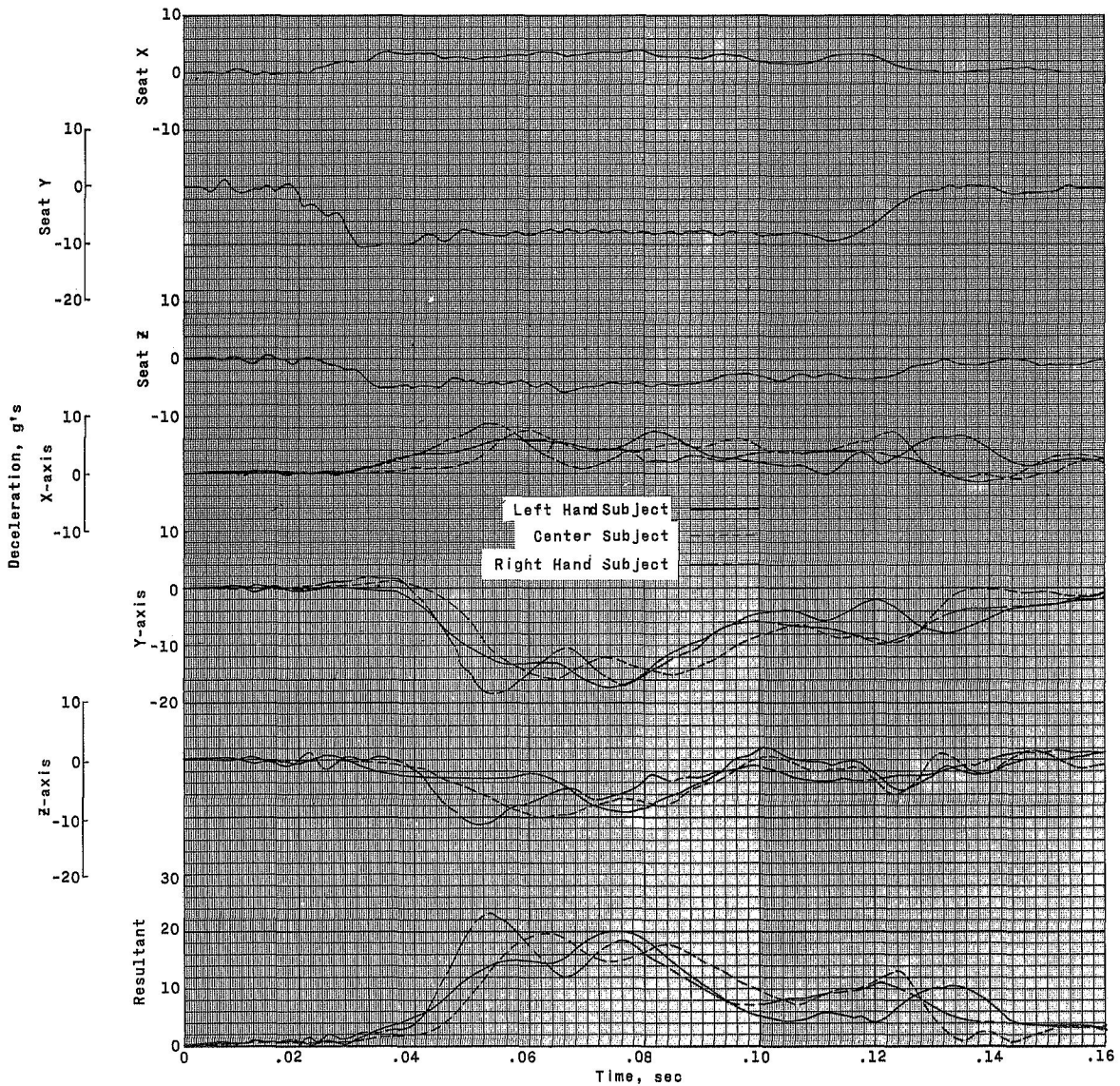


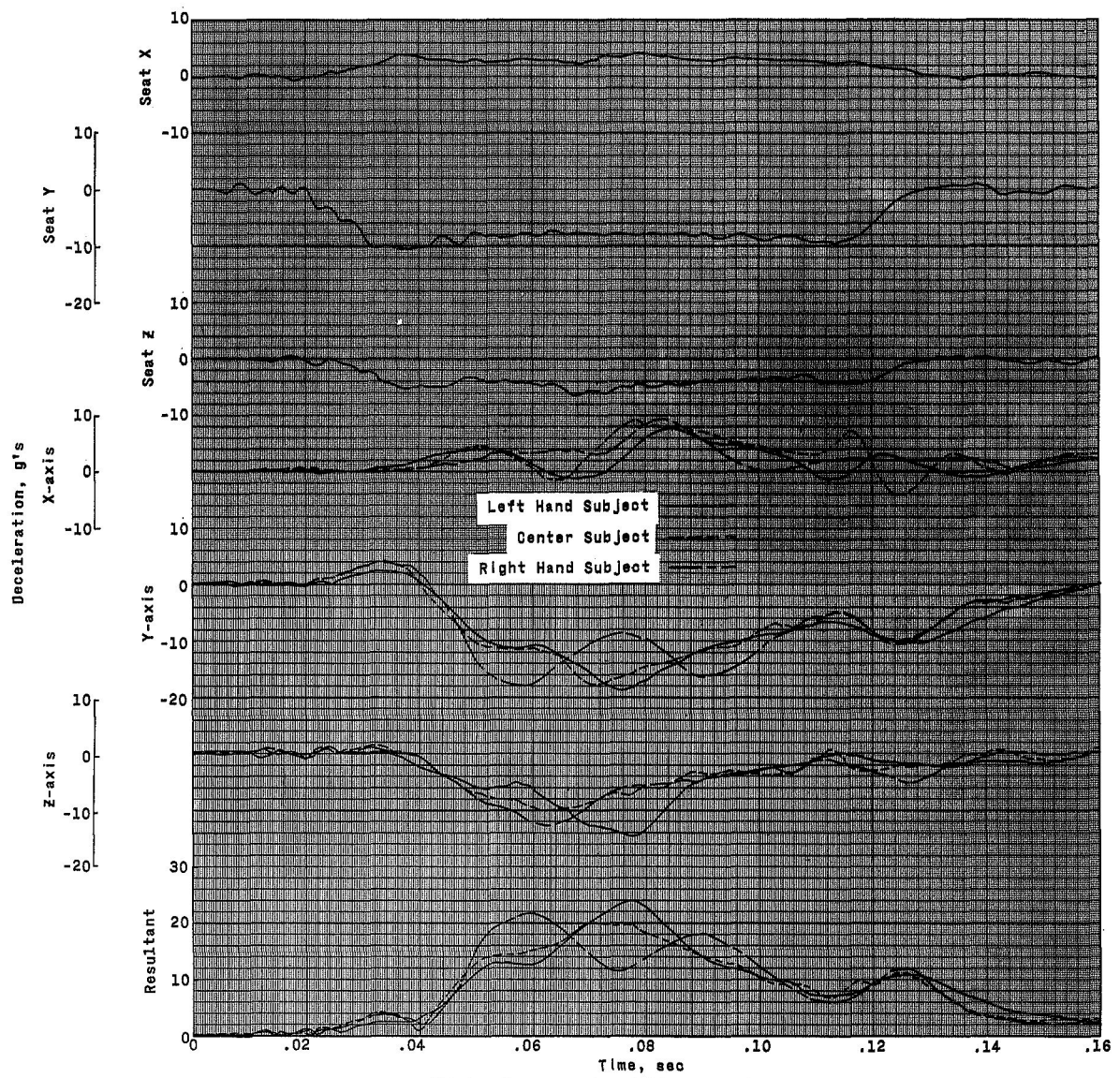
Figure 14.- Comparison of left hand, center and right hand couch occupants deceleration time histories; couch position:  $0^\circ$  roll,  $60^\circ$  pitch and  $30^\circ$  yaw; velocity change 37 fps.



(a) Couch occupant weight plus suit, 165 lbs.

Figure 15.- Comparison of left hand, center and right hand couch occupants deceleration time histories; couch position:  $0^\circ$  roll,  $60^\circ$  pitch and  $60^\circ$  yaw; velocity change 37 fps.





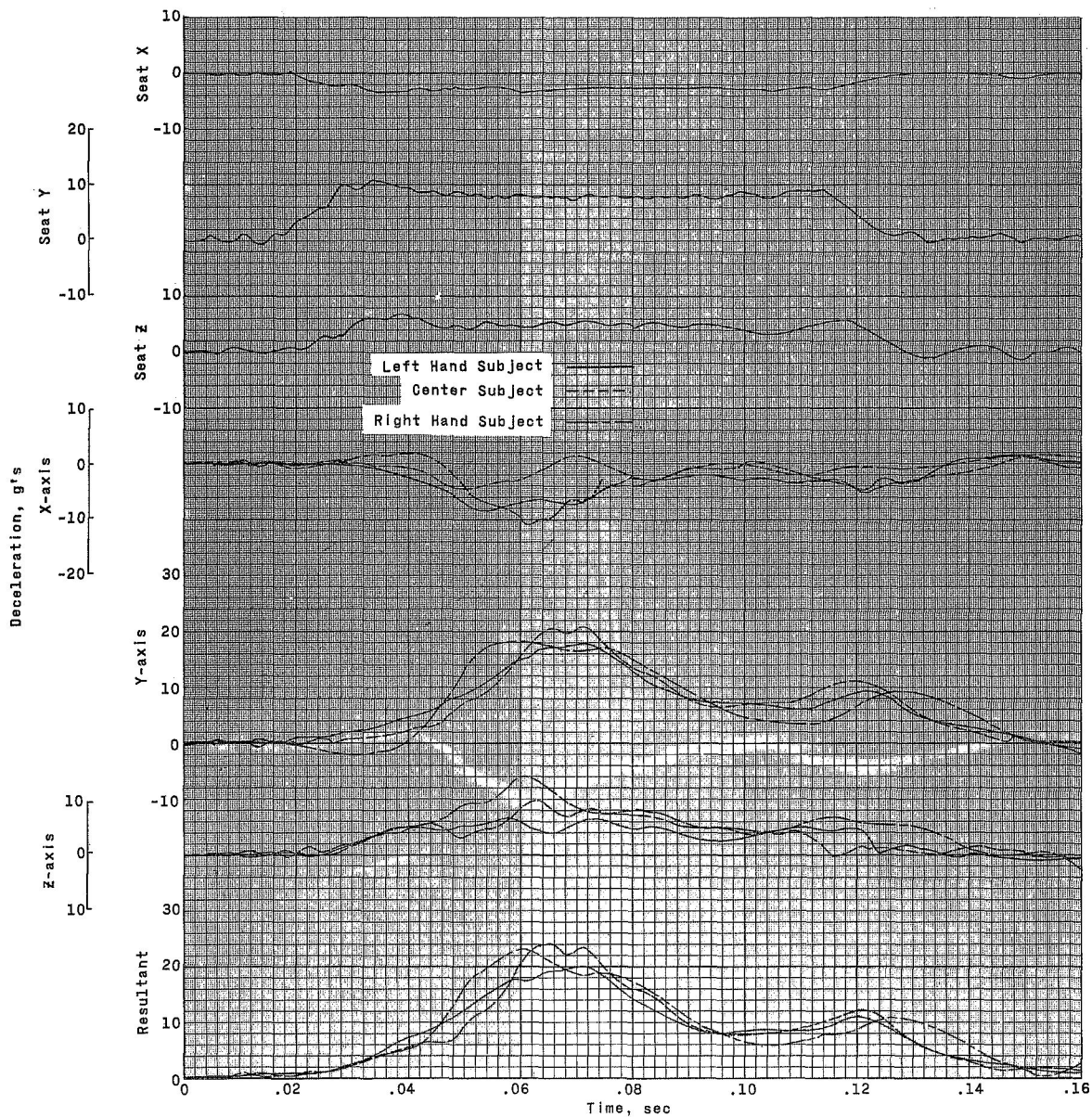
(b) Couch occupant weight plus suit, 190 lbs.

Figure 15.- Concluded.

(b) Couch occupant weight plus suit, 190 lbs.

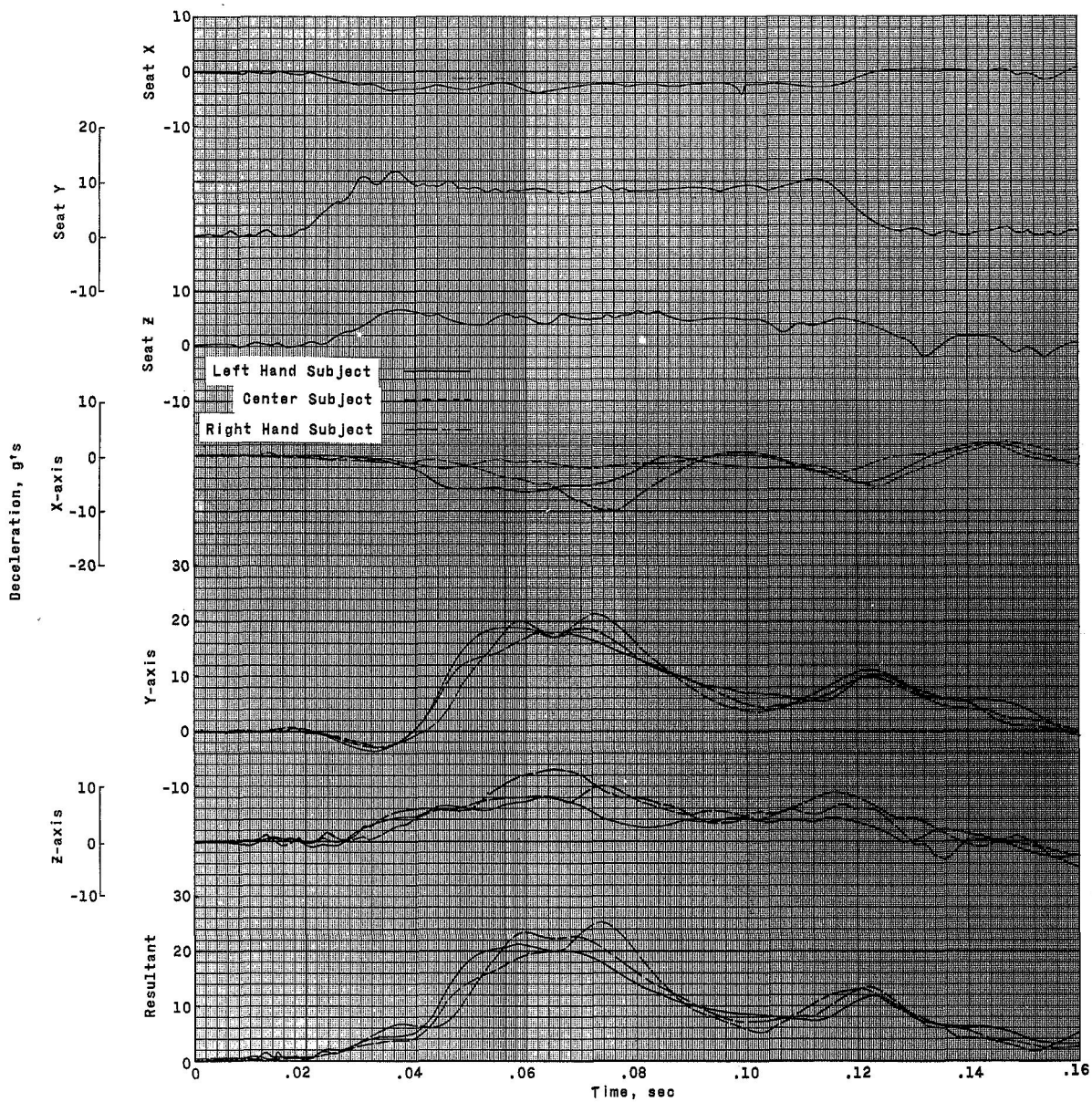
Figure 15.- Concluded.





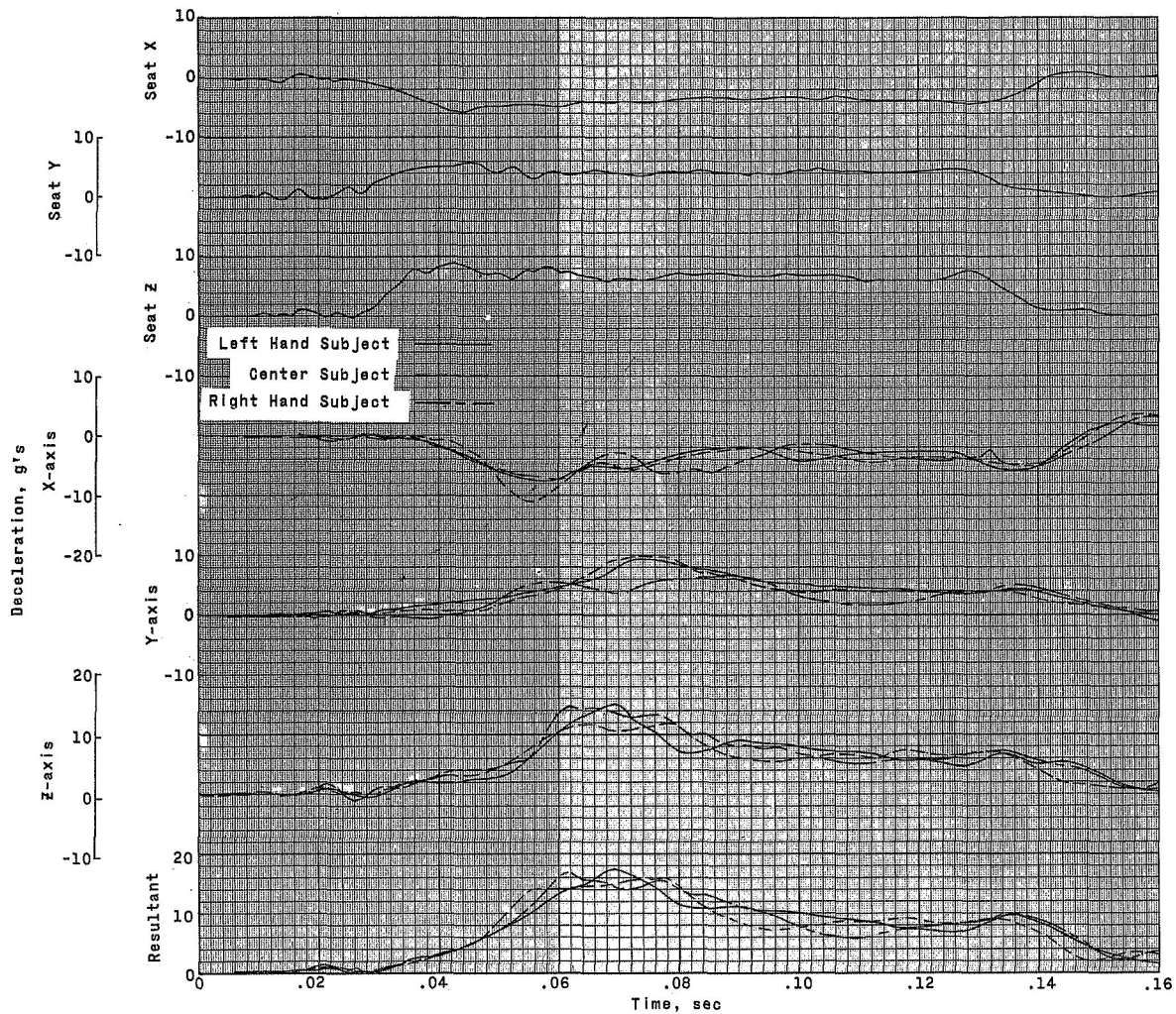
(a) Couch occupant weight plus suit, 165 lbs.

Figure 16.- Comparison of left hand, center and right hand couch occupants deceleration time histories; couch position:  $0^\circ$  roll,  $60^\circ$  pitch and  $210^\circ$  yaw; velocity change 37 fps.



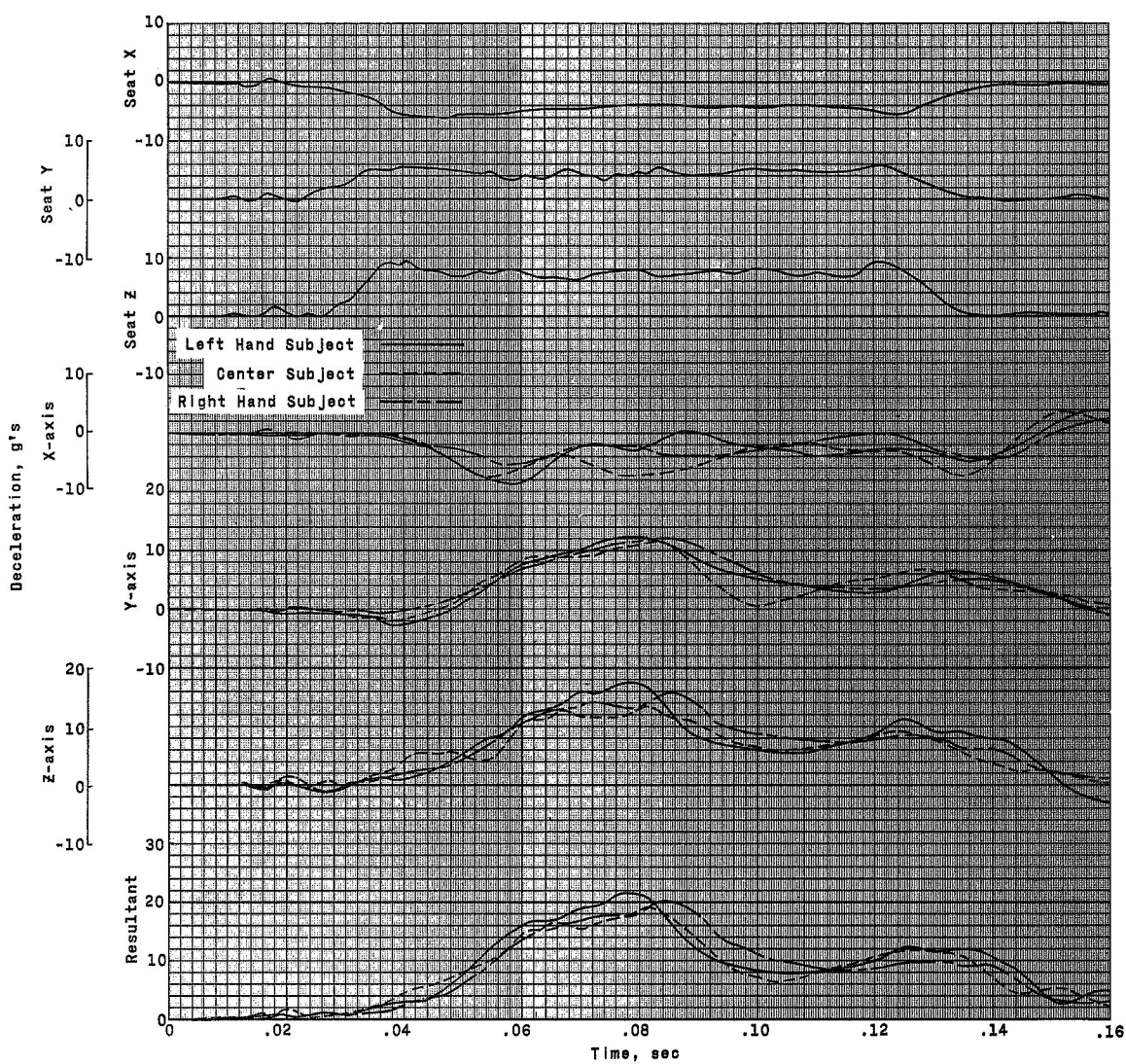
(b) Couch occupant weight plus suit, 190 lbs.

Figure 16.- Concluded.



(a) Couch occupant weight plus suit, 165 lbs.

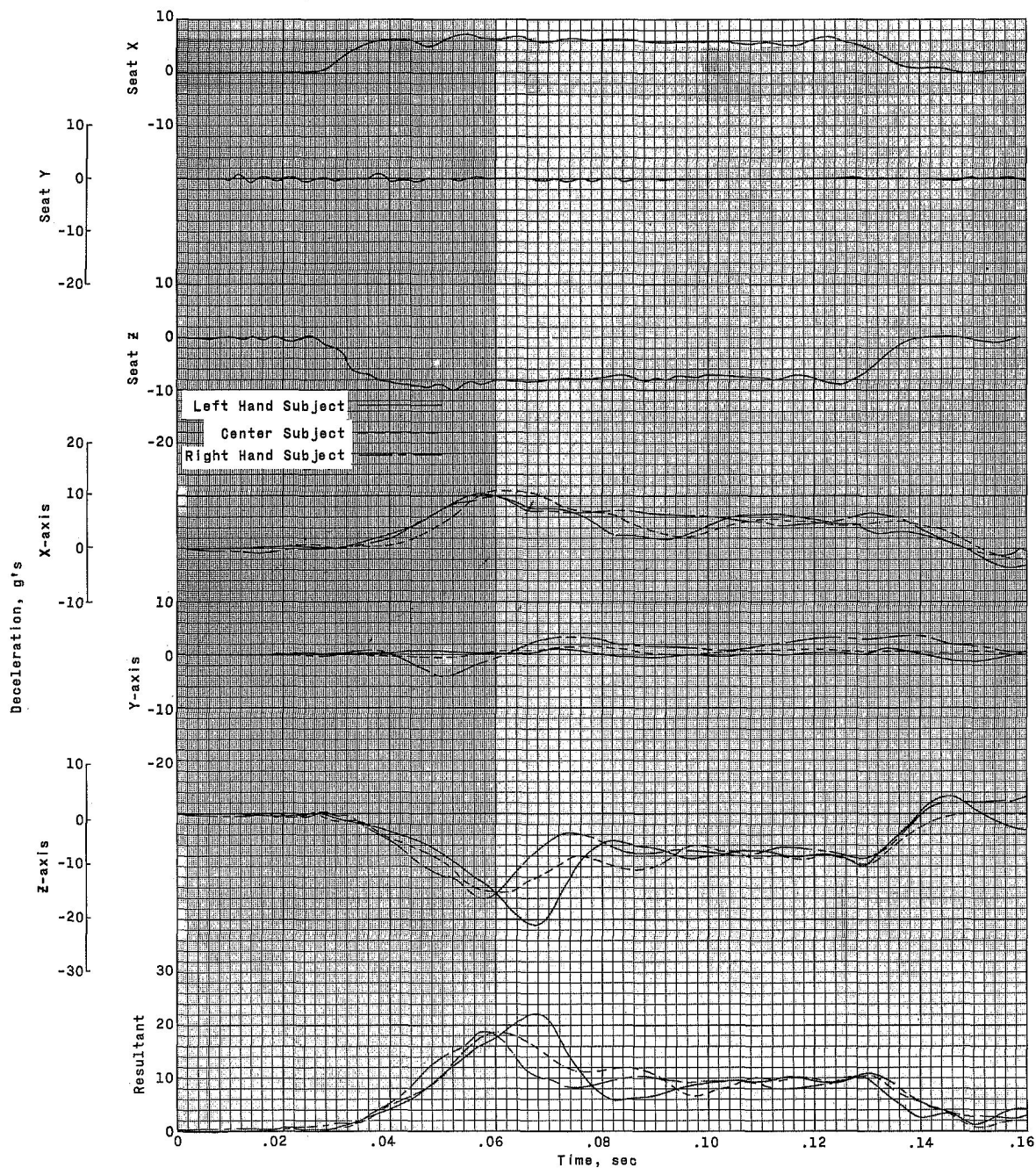
Figure 17.- Comparison of left hand, center and right hand couch occupants deceleration time histories; couch position:  $0^\circ$  roll,  $60^\circ$  pitch and  $240^\circ$  yaw; velocity change 37 fps.



(b) Couch occupant weight plus suit, 190 lbs.

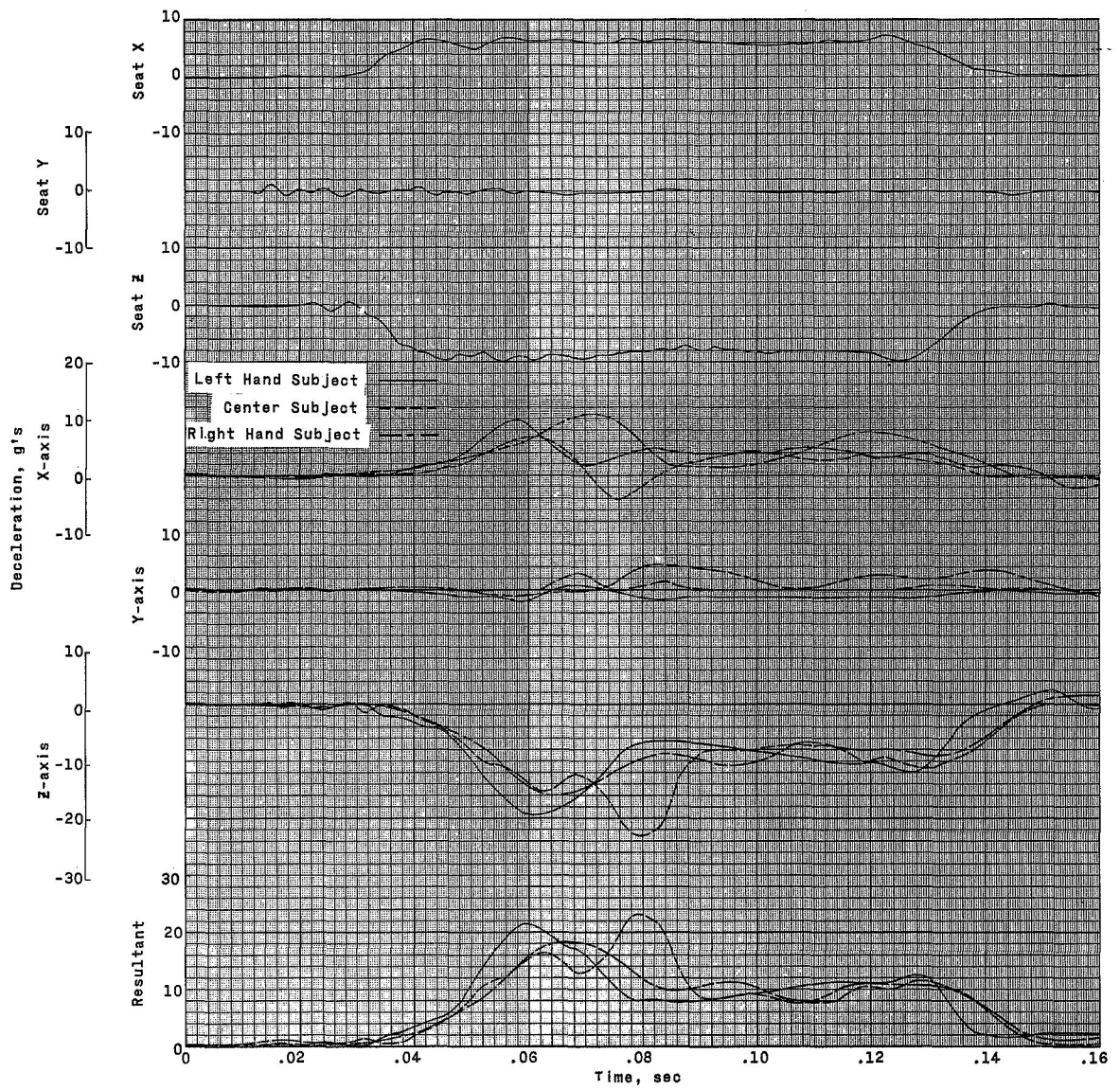
Figure 17.- Concluded.





(a) Couch occupant weight plus suit, 165 lbs.

Figure 18.- Comparison of left hand, center and right hand couch occupants deceleration time histories; couch position:  $0^\circ$  roll,  $60^\circ$  pitch and  $0^\circ$  yaw; velocity change 37 fps.



(b) Couch occupant weight plus suit, 190 lbs.

Figure 18.- Concluded.